Geology of the Deep River Coal Field North Carolina

By JOHN A. REINEMUND

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GEOLOGY OF THE DEEP RIVER COAL FIELD, NORTH CAROLINA

By John A. Reinemund

ABSTRACT

The Deep River coal field is an area of Triassic rocks 36 miles long and from 5 to 14 miles wide that contains the only commercially important beds of coal in North Carolina. These beds crop out along the Deep River and underlie parts of Chatham, Lee, and Moore Counties near the geographic center of the State.

The name "Deep River coal field" is applied to the coal-bearing southwestern half of the Deep River Triassic basin. This basin is a northeast-trending, trough-shaped downfaulted block of Triassic rocks near the east edge of the Piedmont plateau. The northern and southern parts of the basin are more than 10 miles wide and contain from 7,000 to 10,000 feet of Triassic sedimentary rocks; the center of the basin is a constriction 8 miles long and 5 miles wide that contains only 4,000 to 5,000 feet of Triassic sedimentary rocks. The northern and southern parts of the Deep River Triassic basin are called, respectively, the Durham basin and the Sanford basin, and the constriction between them is called the Colon cross structure. Commercially-important beds of coal are present only in the Sanford basin, but the Deep River coal field is usually defined (as described in this report) as including both the Colon cross structure and the southern end of the Durham basin.

On the northwest and southeast the Deep River Triassic basin is bordered by pre-Triassic metamorphic and igneous rocks of the Piedmont plateau. Pre-Triassic metamorphic rocks on the northwest side of the Deep River coal field consist partly of metamorphosed volcanic rocks including acid tuffs and flows, andesite tuffs and flows, and volcanic breccia, and partly of metamorphosed sedimentary rocks including slate, quartzite, and metamorphosed conglomerate. These rocks are part of the "Carolina Slate Belt", a broad area of metamorphic rocks west of the Deep River basin. Pre-Triassic metamorphic rocks on the southeast side of the Deep River coal field consist partly of rocks similar to those on the northwest side, and partly of micaceous and chloritic gneiss and schist, which are similar to rocks in the Wissahickon schist belt that crops out several miles east of the Deep River basin. The metamorphic rocks are cut by irregular Carboniferous(?) granite intrusions along the southeast side of the Colon cross structure and Durham basin.

Triassic sedimentary rocks in the Deep River Triassic basin, which have been assigned to the Upper Triassic Newark group, are clastics composed of debris derived from the pre-Triassic metamorphic rocks and the Carboniferous(?) granite bordering the basin. They consist of claystone, shale, siltstone, sandstone, conglomerate, and fanglomerate characterized by abrupt lateral changes in texture and composition. These deposits are divided into three units: a lower unit called the Pekin formation, which contains mostly red or brown rocks; a middle unit called the Cumnock formation, which contains mostly gray or black rocks and includes two beds of coal; and an upper unit called the Sanford formation, which contains mostly red or brown rocks.

The Pekin formation crops out in a belt along the northwest side of the Deep River basin and lies unconformably on the eroded pre-Triassic rocks. The total thickness of exposed rocks in this formation is from 1,800 to 4,000 feet in the Sanford basin, about 3,500 feet in the Colon cross structure, and 3,000 feet at the south end of the Durham basin. Two-thirds or nine-tenths of the rocks in this formation are red, brown, or purple. In the Sanford and Durham basins, at least three-fourths of the exposed rocks in the Pekin are fine-grained clastics (claystone, shale, siltstone, and fine-grained sandstone); a few beds of conglomerate are in the basal 50 to 500 feet of the formation. In the Colon cross structure only about half of the exposed rocks in the Pekin are fine-grained, and beds of conglomerate are abundant in all parts of the formation.

The Cumnock formation, which lies conformably on the Pekin, crops out in a narrow belt in the Sanford basin and at the south end of the Durham basin; it is not present in the Colon cross structure. The Cumnock formation is thickest (750 to 800 feet) in the eastern part of the Sanford basin, where it contains two beds of coal: the Gulf coal bed, which is generally less than 2 feet thick; and the Cumnock coal bed, which is generally less than 4 feet thick. These coal beds are separated by 30 to 40 feet of gray shale, siltstone, and fine-grained sandstone. The coals in this part of the basin are underlain by about 250 feet of gray shale, claystone, siltstone, and sandstone, and they are overlain by about 500 feet of gray and black shale and claystone, which are irregularly calcareous, carbonaceous, and fossiliferous. In the western part of the Sanford basin, the Cumnock formation is about 500 feet thick; it consists mostly of siltstone and sandstone and contains no coal. At the south end of the Durham basin the Cumnock is not more than a few hundred feet thick; it consists mostly of silty shale, siltstone, and sandstone, and contains only a few inches of coal. In the Colon cross structure the Cumnock formation grades laterally into red and brown sandstone and conglomerate, which are similar to strata in the Pekin and Sanford formations.

The Sanford formation crops out along the southeast side of the Deep River basin in an irregular area that is broad in the Durham and Sanford basins and narrow in the Colon cross structure. This formation is more than 3,000 feet thick in the Sanford basin, 2,000 to 3,000 feet thick at the south end of the Durham basin, and from 500 to 600 feet thick at the southwest end of the Colon cross structure. More than three-fourths of the rocks in this formation are red, brown, or purple. In the Sanford basin and at the south end of the Durham basin, the Sanford formation consists mainly of fine-grained clastics, but in the Colon cross structure about four-fifths of the formation is conglomerate and fanglomerate. Toward the southeast most rocks in this formation are coarser-grained and form a nearly-

continuous belt of conglomerate and fanglomerate along the southeast edge of the Deep River basin.

The basal conglomerate of the Pekin formation was derived largely from pre-Triassic metamorphic rocks located a short distance northwest of the Deep River basin, but most of the overlying Triassic sediments are composed of debris from erosion of the pre-Triassic metamorphic and igneous rocks southeast of the basin. Poorly-bedded, unsorted, boulder-bearing sediments were deposited in alluvial fans at the southeast edge of the basin by streams flowing northwest out of an adjacent highland area; finer-grained, better-sorted sediments were deposited farther northwest in the centers of the Sanford and Durham basins. A large alluvial fan existed in the Colon cross structure during most of the Newark epoch, and sandstone and conglomerate were deposited in this fan at the same time that finer-grained sediments, including coal and gray or black shale, were deposited in the Sanford and Durham basins on either side of it.

Sediments in the Pekin and Sanford formations are channel and floodplain deposits that accumulated on well-drained slopes favorable for oxidation and consequent destruction of any included organic material. Red or brown colors, which may have formed partly by weathering of the rock debris in the source area, were thereby preserved and accentuated. Sediments in the Cumnock formation are lake and swamp deposits that accumulated in an environment favorable for the preservation of organic material and for the reduction of any ferric oxides and consequent loss of red and brown colors in the sediments. The coal and gray and black shale in the Cumnock formation probably record a period of temporary drainage ponding in the Deep River basin.

Deep River Triassic sediments consist partly of weathered debris derived from the regolith in the sediment source area and partly of fresh debris derived from newly-exposed bedrock in the source area; they consist partly of feldspar-rich debris derived from feldspathic igneous and metamorphic rocks and partly of feldspar-poor debris derived from non-feldspathic metamorphic rocks near the Deep River basin. The proportions of fresh or weathered, feldspathic or non-feldspathic debris in these sediments are related to the amount of weathering, the depth of erosion, and the composition of the bedrock in the source area.

Red and brown fine-grained clastics, and matrices of most coarse-grained clastics in the Pekin and Sanford formations, consist of oxidized, weathered debris, but lenses of gray, coarse-grained sandstone and conglomerate, composed mainly of fresh rock particles, are present particularly in the lower part of the Sanford formation. Most rocks in the Deep River Triassic basin contain less than 15 percent feldspar, but rocks containing more than 25 percent feldspar are present locally. Most of the sandstone, conglomerate, and fanglomerate contain large amounts of metamorphic rock fragments, and some of these may properly be called schist-arenites. In some places the Triassic rocks contain 5 percent or more of olivine and pyroxene; locally they contain 2 to 6 percent of magnetite and ilmenite. The medium- and coarse-grained clastics are held together partly by quartz cement, partly by clay paste, and partly by an intricate inter-locking of the angular rock particles.

The Triassic sedimentary rocks in the Deep River coal field have been intruded by late Triassic, or possibly Jurassic, basic dikes, sills, and sill-like masses that are partly controlled by bedding. The dikes are from a fraction of an inch to more than 300 feet wide and are from a few feet to more than 7 miles long. Most dikes trend N. 15°—40° W.; few extend into the pre-Triassic rocks beyond the Deep River basin. The dikes generally make sharp, straight contacts with the rocks they intrude, but in faulted areas the dikes are usually discontinuous, and the contacts are irregular. Sills and sill-like intrusives, a few inches thick to more than 100 feet thick, are present in the Sanford basin (mostly in the upper part of the Cumnock formation). They are most extensive in areas of intense faulting in the western part of the coal-bearing area.

Basic intrusives in the Deep River coal field range from dioritic diabase, which consists of augite, plagioclase, and micropegmatite, to gabbroic diabase, which consists mainly of olivine, plagioclase, and augite. In general, the Deep River intrusives are more basic than the diabase intrusives in the other Triassic basins of eastern United States; they contain more olivine and calcic plagioclase, and they do not exhibit syenitic differentiates similar to those in other basins.

The intrusives have had relatively unimportant effects on the other Triassic deposits, but they have metamorphosed the coal to semianthracite, anthracite, and coke. Coke is present only in narrow zones, less than 10 feet wide, bordering intrusives in contact with the coal beds; anthracite and semianthracite are present extensively in the western part of the coal-bearing area, where sills and sill-like intrusives are near the coal beds.

Triassic and pre-Triassic rocks along the southeast side of the Sanford basin are partly covered by surficial sand and gravel deposits as much as 130 feet thick along the inner edge of the Coastal Plain. These deposits extend completely across the southwest end of the Sanford basin. They are tentatively classed as Pliocene(?), but may be in part Cretaceous. River terrace deposits of probable Pleistocene age are present at four levels along the rivers, and Recent alluvium covers broad areas along some streams in the Deep River coal field.

The Deep River Triassic basin is a tilted and downfaulted trough-shaped block, in which the Triassic sedimentary rocks dip generally southeastward. The northwest edge of this basin is formed, in most places, by the irregular sedimentary contact at the base of the Pekin formation; the southeast edge is formed by the Jonesboro fault, a northwest-dipping normal fault having a minimum vertical displacement equal to the maximum thickness of Triassic sediments in the basin (7,000 to 10,000 feet).

Two systems of normal faults have broken the Deep River basin into structurally discordant fault blocks. Northeast-trending longitudinal faults, roughly paralleling the Jonesboro fault, are present in the northwestern part of the Sanford basin and probably are present in the Durham basin also. These faults have displacements of several hundreds or thousands of feet. Northwest-trending cross faults, which are commonly followed by dikes, are present in all parts of the Sanford basin and Colon cross structure and in the southern part of the Durham basin. These faults have displacements ranging from a few feet to a few hundred feet. Tilting and differential subsidence within the rectangular fault framework produced by these two systems of faults have resulted in many variations from the regional strike and dip of the beds, in variable displacements along faults, and in abrupt changes of attitude and relative elevation of beds in the Deep River basin.

The Colon cross structure is an anticlinal constriction near the center of the Deep River basin, and it separates the Sanford basin from the Durham basin. This anticline is a result of differential subsidence of the Deep River basin that occurred mostly after the Triassic sediments were deposited.

Structural development of the Deep River basin was by tilting and spasmodic subsidence along the Jonesboro fault and probably was accompanied by uplift and erosion of the sediment source area southeast of the fault. After the sediments in the basin were deposited, the cross faults were formed as relatively deep tensional cracks. Renewed longitudinal faulting then occurred, and several new longitudinal faults were formed. Basic magma welled up along the cross faults and spread out along the bedding in places, and locally it spread along the longitudinal faults. After a long period of erosion both the Triassic and adjoining pre-Triassic rocks were peneplaned, and a large part of the original Triassic basin was eroded away. Coastal Plain sediments subsequently deposited on the peneplane surface are now being stripped away.

Coal mining was started in the Deep River coal field prior to the Revolutionary War and has been carried on intermittently since that time. A little more than a million tons of coal have been produced. Most of this production came from the Cumnock and Carolina mines, and all but a few hundred tons came from the Cumnock coal bed.

The Cumnock coal bed underlies an elliptical area of about 75 square miles in the northeastern part of the Sanford basin; it is 3 to 4 feet thick over a large part of this area and becomes progressively thinner toward the east, south, and west. In the eastern part of the coal-bearing area, the Cumnock is a bituminous coal having fixed carbon contents ranging from about 52 to 60 percent on an "as received" basis, ash contents ranging from about 6 to 16 percent, sulfur contents ranging from about 1 to 4 percent, and heating values ranging from about 12,000 to 14,000 B. t. u. In the western part of the coal-bearing area the Cumnock has been extensively metamorphosed to semi-anthracite and anthracite, and very little of this coal has been mined. The Gulf coal bed, which is 30 to 40 feet below the Cumnock coal bed, underlies a much smaller area than the Cumnock; it is generally only about half as thick and of poorer quality.

The total reserve of unmined coal in the Deep River field is estimated to be 110,337,000 short tons, of which only about half is recoverable. All but about 10,000,000 tons of this reserve is in the Cumnock coal bed. Almost the entire reserve of mineable coal (at least 3 feet thick) in the Deep River coal field lies in a canoe-shaped graben bounded by two longitudinal faults—the Deep River fault and the Gulf fault—in the northwestern part of the Sanford basin. Although the coal in this graben is deeply buried, large sub-blocks in the graben contain coal that is relatively undisturbed by faulting. The future of the coal mining industry in the Deep River field lies in the extraction of this coal.

Beds of ferruginous, carbonaceous shale (known as blackband) are associated with the Cumnock and Gulf coal beds in the Deep River coal field. These blackband beds yield small amounts of shale oil when heated. They contain $Ca_3(PO_4)_2$, in amounts averaging about 20 pounds per ton, and $(NH_4)_2SO_4$, in amounts averaging about 43 pounds per ton, and they have been used in the manufacture of fertilizer. The iron content of the blackband beds averages about 15 percent.

Clays in the Sanford and Pekin formations are used extensively in the manufacture of brick and tile. Recent research has shown that some of these clays are suitable for the production of portland cement when combined with limestone from eastern North Carolina.

Pre-Triassic rocks bordering the Deep River basin contain important deposits of pyrophyllite and small deposits of iron, copper, and gold.

INTRODUCTION

LOCATION AND EXTENT OF THE AREA

In North Carolina the only commercially important beds of coal underlie parts of Chatham, Lee, and Moore Counties and crop out along the Deep River. The area containing these beds is known as the Deep River coal field. This field is near the geographic center of the State. The town of Sanford, located at the southeast edge of the coal field in Lee County, is about 45 miles southwest of Raleigh, 60 miles south of Greensboro, and 125 miles east of Charlotte.

This report describes the geology of the Deep River coal field and adjacent territory, which covers an area 36 miles long and 10 to 15 miles wide. The northeast end of this area is in southeastern Chatham County near the villages of Merry Oaks and Corinth; the southwest end is in western Moore County, 3 miles southwest of Carthage. Goldston, in southern Chatham County, and Lemon Springs, in central Lee County, are near the northwest and southeast edges of the area, respectively. The outline and location of the territory described in this report are shown on the index map of North Carolina (fig. 1). The geographic positions of communities in and near the coal field are shown on the geologic map (pl. 1).

REGIONAL RELATIONS AND NOMENCLATURE

The Deep River coal field is part of the Deep River Triassic basin—one of many narrow, structurally and stratigraphically similar basins that contain Triassic rocks and are scattered discontinuously along the Atlantic seaboard from Nova Scotia to South Carolina. In North Carolina there are four Triassic basins aligned in two northeast-trending belts 70 miles apart (see fig. 1). The Dan River and Davie County basins in the western part of the Piedmont plateau form a disconnected western Triassic belt that includes the Danville basin of southern Virginia. The Wadesboro and Deep River basins form an eastern Triassic belt that extends across the center of North Carolina, lies along the east edge of the Piedmont plateau, and is partly covered by an overlap of younger deposits along the inner edge of the Coastal Plain.

The Deep River basin is the largest of the Triassic basins in North Carolina. It is a structural and topographic trough almost 100 miles long and 5 to 20 miles wide. It is bounded on the west, north, and east by pre-Triassic metamorphic and igneous rocks of the Piedmont plateau. On the southeast and south, a cover of post-Triassic deposits along the inner edge of the Coastal Plain gradually overlaps and progressively conceals the Triassic and older rocks (see fig. 2). At

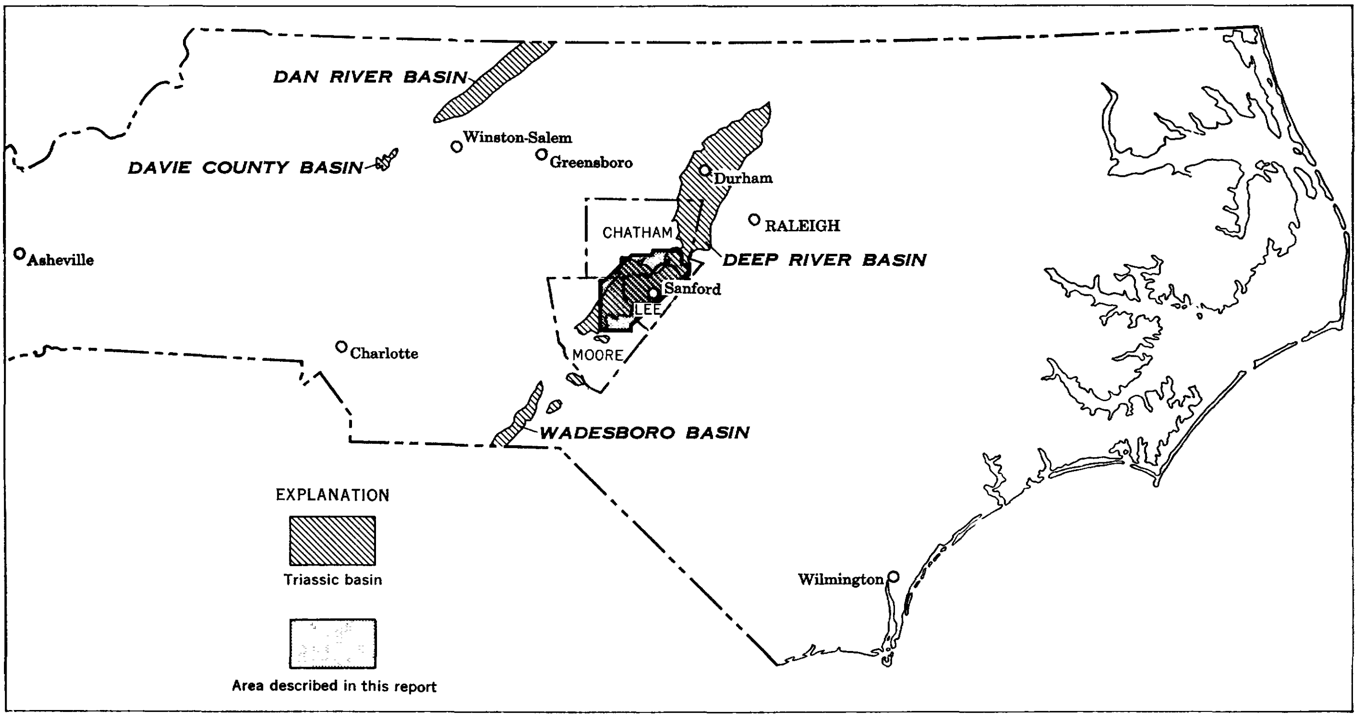


FIGURE 1.—Index map of North Carolina showing Triassic basins and area described in this report.

the southwest end of the basin, this overlap extends across the entire Triassic belt, dividing the belt and separating the Wadesboro basin from the Deep River basin.

Physiographically, structurally, and lithologically, the Deep River Triassic basin is divisible into three parts. The northern and southern parts of the trough are relatively broad, deep basins; the width of the Triassic belt in these basins generally exceeds 10 miles, and the total thickness of the Triassic sedimentary rocks ranges from 7,000 to 10,000 feet. These basins are separated by a constriction near the center of the trough wherein the Triassic belt is only about 5 miles wide and the thickness of the Triassic rocks is 4,000 to 5,000 feet. Prouty (1926) has named the northern and southern segments of the Deep River Triassic basin, respectively, the Durham basin and the Sanford basin—named for the largest city in each basin. The center constriction is known as the Colon cross structure; this name was first applied by Campbell and Kimball (1923, p. 54–55) to a part of this constriction, but here it is redefined and extended to include all of the constriction. These three parts of the Deep River Triassic basin are shown in figure 2.

The Durham basin is about 52 miles long and has a maximum width of 20 miles. It extends from east-central Granville County southwest to the northeast end of Lee County and includes parts of Granville, Durham, Orange, Wake, and Chatham Counties. The city of Durham is in the northern part of this basin, and the city of Raleigh is 10 miles east of its eastern border.

The Colon cross structure is 8 miles long and 5 miles wide. It lies entirely in northeastern Lee County and extends from the northeast edge of the county southwest to the village of Colon, 4 miles northeast of Sanford.

The Sanford basin extends from Colon southwest for a distance of 32 miles to the end of the Deep River basin in western Moore County. It has a maximum width of 14 miles. It includes parts of Lee, Moore, and Chatham Counties. Sanford is near the northeast end, and Carthage is near the southwest end of the basin.

Previous workers have applied the name Deep River coal field to the entire southern half of the Deep River Triassic basin, including the Sanford basin, the Colon cross structure, and the south end of the Durham basin. This usage of the name is retained in this report to designate that part of the Deep River basin shown on the geologic map (pl. 1), and outlined in figure 1, even though only a small part of this territory is underlain by coal. Inasmuch as this territory is geologically heterogeneous, however, the names Sanford basin, Colon cross structure, and Durham basin will be used in describing the geology of different parts of the Deep River coal field.

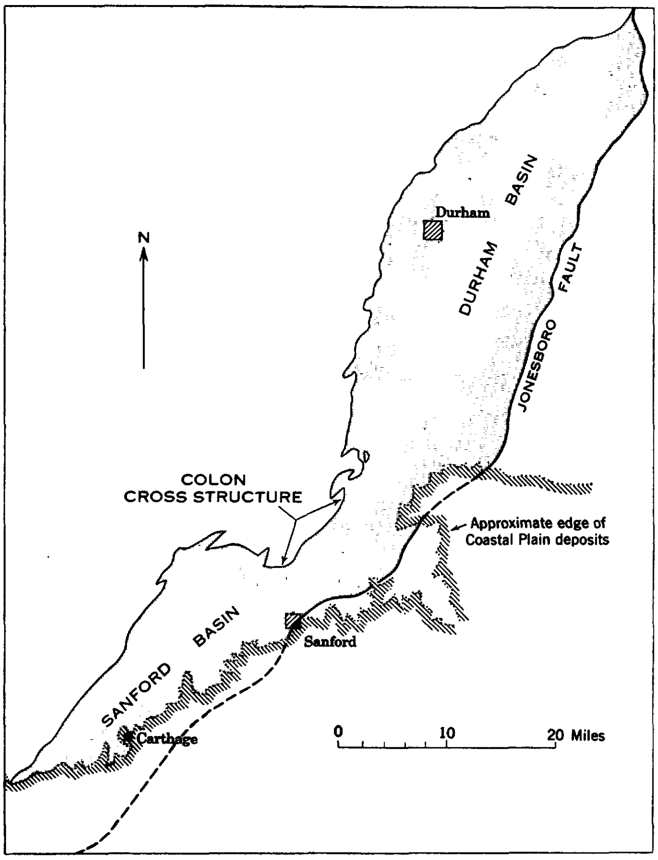


FIGURE 2.—Index map of the Deep River Triassic basin showing locations of Sanford basin, Colon cross structure, and Durham basin.

PREVIOUS INVESTIGATIONS

Geologic investigations of the Deep River coal field cover a span of 130 years. The first published accounts of the Deep River region were by Olmstead in 1820 (p. 175–176), when he called attention to the sandstones with which the coal is associated, and in 1824 (p. 12–23), when he outlined the limits of the Deep River Triassic basin in which the coal is contained, briefly described the Triassic sedimentary rocks in which the coal occurs, and discussed the known occurrences of coal in the Deep River field. In 1851 Johnson (p. 9–17) presented the first analytical data on the quality of the coal. Emmons (1852, p. 119–143, 153–159; 1856, p. 227–254, 261–342) made the first comprehensive survey of the field as a part of his geological survey of North Carolina during the years 1851 to 1856. He listed the characteristics and sequence of the Triassic formations, mapped the general extent of the coal and related shales, and assembled and described a collection of fossils that has formed the basis for all subsequent paleontologic correlations and age determinations.

In the years from 1856 to 1923 additional information on the quality of the coal, iron, and other resources of the region was made available in analyses published by Wilkes (1858), Kerr (1875), Chance (1885), Battle (1885–86), Clarke (1887, p. 138, 146), and others. Chance's report, which was based on extensive prospecting and examinations of mine workings along the coal outcrop, provided the first detailed information on the thickness and lateral extent of the coal. Studies of the fossil collections of Emmons by Redfield (1856, p. 363) and by Fontaine (1883) led to the determination of the age of the coal-bearing rocks and of the age-equivalence of the rocks of the Deep River coal field with those of other Triassic basins in eastern United States. The general geologic relationships of the Deep River field and of the other Triassic basins were discussed by Russell (1892). In 1898, Ward (1898–99, p. 266–315) summarized the paleobotanical information obtained from the collections of Emmons and Russell,[1] and Woodworth (1902, p. 31, 43–53) gave a brief summary of the geology of the field with coal analyses and production statistics.

The last comprehensive study of the Deep River coal field prior to the present investigation was by Campbell and Kimball (1923). Their report defined and named the formations, briefly described the general structure of the field, summarized the data on quality, thickness, and extent of the coal, and indicated the probable coal reserves. The stratigraphy of the coal field was briefly summarized by Bryson (1924). Papers by Vilbrandt (1924, 1926, 1927), and by Murphy and Vilbrandt (1930), have furnished additional information on the quality and usefulness of the coal and bituminous shales.

A number of additional reports, some of more general scope, some describing areas adjoining the Deep River coal field, and some dealing with related problems and areas, are cited at appropriate places in this report. A complete bibliography of reference publications appears at the end of the report.

PURPOSE AND SCOPE OF THE REPORT

Published reports on the Deep River coal field have dealt in detail with some of the geologic problems of the area, but some problems were treated only briefly. At the start of the present investigation the status of geologic information available in previous publications was as follows:

1. The general limits of the Deep River Triassic basin containing the Deep River coal field were well known, but the boundaries of the Triassic had never been systematically studied and accurately mapped.[2]

[1] Ward's paper includes additional descriptions of the Emmons collection by Fontaine, and descriptions by Knowlton of specimens collected by Russell.

[2] The west border of the Durham Triassic basin northeast of the Deep River coal field was described in detail by Harrington (1951).

2. General descriptions of the stratigraphy of the coal field had been made, and the formations had been defined and named. The general characteristics and thicknesses of the formations in the center of the field were well known, but very little was known about the lateral continuity of formations northeast and southwest of the center of the field.

3. Very little information was available on the mineralogy, textures, and facies changes of the Triassic sedimentary rocks, and the only information about the sedimentary processes that formed these rocks was obtained by analogy with other Triassic areas.

4. Considerable information on fauna and flora was available, and the age of the formations had been tentatively established.

5. The structure of the Deep River basin was imperfectly known. Previous workers had determined the general attitude of the Triassic strata, the existence of the fault forming the southeast border of the basin, and the presence of a few of the faults within the basin. However, the locations, magnitude, and significance of most structures within the basin were not known, and the structural development of the field was poorly understood. This was particularly unfortunate because lack of knowledge of the faulting in the mine areas seriously impeded mine operation and resulted in many costly mine failures.

6. The forms of diabase intrusives in the Deep River field had been briefly described, but little information was available on the petrography, extent, and significance of these intrusives.

7. Although considerable information was available concerning the thickness, extent, quality, and reserves of coal, much additional information (obtained through mining and drilling within the past decade) had not been compiled and published.

8. The geomorphic features and history of the region had received very little attention.

This report is, in part, a compilation of the important geologic information on the Deep River coal field from earlier publications, from various unpublished sources, and from records of recent mining and drilling. In addition, it presents the results of a detailed investigation of the Deep River field made between 1946 and 1949, which was undertaken to prepare an up-to-date geologic map of the Deep River coal field; to obtain additional information on the mineralogy, texture, thickness, and lateral continuity of the Triassic formations; to determine the locations, sequence, and magnitude of faults within the Triassic basin; to study the extent and significance of the diabase intrusives; and to obtain additional data on the thickness, quality, and extent of the coal which would provide an improved estimate of the reserves and of the value of the coal in this field.

PREPARATION OF THE REPORT

Geologic investigations for this report were started in the Deep River coal field in December 1946 and continued until January 1949. Field work consisted of geologic mapping of the entire area on aerial photographs (scale 1:20,000), detailed topographic and geologic mapping of the Cumnock-Carolina mine area, subsurface mapping of the Carolina mine, and examination of cores from holes drilled by the Bureau of Mines during this period. Altitudes were determined by aneroid traverses, and additional mapping was completed on two brief visits to the field in the summers of 1949 and 1950. Preparation of illustrations, tables, and text for this report was carried on during 1949, 1950, and 1951. A map summarizing the preliminary results of this investigation was published in June 1949 (Reinemund, 1949).

The preparation of this report was facilitated by the generous cooperation of many individuals. Drilling information was provided by Howard N. Eavenson (5 holes drilled for Eavenson, Alford, and Hicks in 1930), by Coal Products, Inc. (1 hole drilled in 1944), by Walter Bledsoe and Company (11 holes drilled in 1945–46), and by the U. S. Bureau of Mines (6 holes drilled in 1944–45 and 2 holes drilled in 1947–48). Mine maps and information were provided by J. S. Marshall of the Raleigh Mining Company, and T. K. Howard of that company generously assisted in the underground mapping of the Carolina mine. T. R. Jolley of the U. S. Bureau of Mines gave valuable aid in mapping the Cumnock-Carolina mine area, and J. J. Shields and W. A. Haley cooperated in obtaining core samples and analyses. During May, June, and July of 1947, Salvador Cortez Obregon assisted in the field investigations. Dr. J. L. Stuckey, State Geologist of North Carolina, furnished much valuable information and took an active interest in the project. The assistance and cooperation of these individuals and organizations, and of many residents of the Deep River field, are deeply appreciated.

GEOGRAPHY

TOPOGRAPHY

Triassic sedimentary rocks of the Deep River basin are more easily eroded than either the metamorphic and igneous rocks of the Piedmont plateau or the porous sand and gravel deposits of the Coastal Plain. The Triassic belt, therefore, is a troughlike topographic lowland for most of its length, bounded on the northwest, north, and east by the upland surface of the Piedmont plateau and on the southeast and south by the upland surface of the Coastal Plain. Differences in structure and lithology of the rocks, and in geomorphic history, have resulted in slight differences in the topography of the Triassic lowland, the Piedmont plateau, and the Coastal Plain.

TOPOGRAPHY OF THE TRIASSIC LOWLAND

The Triassic lowland is an intricately dissected surface with a local relief that is generally less than 100 feet. Interstream divides are sharp and narrow near the main streams, but farther from the main drainage lines they become higher, broader, and flatter. In the Sanford basin, the general slope of the surface is toward the Deep River, which flows across the northern part of this basin; in the Colon cross structure and in the southern Durham basin the general slope is toward the Cape Fear River, which crosses the Triassic lowland at the south end of the Durham basin. There are few prominent ridges or hills in the lowland; the highest ridges in the mapped area are formed on beds of siltstone or fine-grained sandstone in the western part of the Sanford basin. Terraces along the Deep, Haw, and Cape Fear Rivers, and along some of the larger creeks, form the most extensive flat areas in the lowland.

Most streams in the Triassic lowland are actively deepening their valleys. As a result, valley sides are usually steep and valley bottoms are narrow. Narrow flood plains are present along the rivers and their larger tributaries. Some of these tributaries, such as McLendons Creek in Moore County and Cedar Creek in Chatham County, have swampy flood plains for a few miles upstream from their junctions with Deep River. There is very little swampy land along this river, however; the river is now removing a previous alluvial fill and cutting down into bedrock at many places.

Altitudes in the Triassic lowland range from less than 160 feet above sea level along the Cape Fear River to more than 500 feet above sea level in some parts of the Durham basin. Within the mapped area the lowland is generally 200 to 350 feet above sea level and 50 to 200 feet below the adjacent surfaces of the Piedmont plateau and Coastal Plain.

Most of the Triassic boundaries are abrupt topographic escarpments. A south-facing escarpment marks the contact between Triassic and pre-Triassic rocks along the northwest side of the Deep River basin everywhere except northeast of the Carolina mine and west of Glendon. This escarpment is highest west of Moncure at the northwest edge of the Colon cross structure. A prominent north-facing escarpment is present along the Triassic–pre-Triassic contact at the southeast edge of the Colon cross structure; this slope is utilized by the reservoirs of the Sanford water works. Farther west, along the southeast edge of the Sanford basin, this north-facing escarpment follows approximately the irregular inner edge of the Coastal Plain deposits and reaches a height of about 250 feet at Carthage (see pl. 2).

TOPOGRAPHY OF THE PIEDMONT PLATEAU

Most of the Piedmont plateau northwest of the Deep River coal field is a gently rolling upland with shallow valleys and rounded divides. When viewed from the top of the escarpment at the southeast edge of the Triassic trough, this surface appears to be remarkably flat and smooth, interrupted only by a few monadnocks rising not more than a few hundred feet above the plateau in northern and western Chatham County and in adjacent counties. Within the area covered by the geologic map (pl. 1), there are no monadnocks or outstanding ridges, but the Piedmont surface is deeply dissected near the Deep, Rocky, and Haw Rivers and along the Triassic border.

From northern Lee County, where its average altitude is between 350 and 375 feet above sea level, the Piedmont gradually rises toward the west and north. In northwestern Moore County the altitude is generally between 400 and 450 feet, in central Chatham County it is between 450 and 500 feet, and in the northwest corner of Chatham County the plateau has an altitude of about 600 feet. Pratt (1917, p. 71) lists the following altitudes for points in the Piedmont northwest of the Deep River coal field: Pittsboro (east-central Chatham County), 480 feet; Ore Hill (west-central Chatham County), 495 feet; Siler City (northwestern Chatham County), 590 feet.

Partly exposed by the removal of the Coastal Plain cover, pre-Triassic crystalline rocks crop out along the southeast edge of the Deep River Triassic basin east of Sanford. The surface thus exposed is the equivalent of the Piedmont plateau surface on the northwest side of the trough, and it has about the same elevation (350 to 400 feet). This area of pre-Triassic rocks is intensely dissected because of its proximity to the Triassic lowland and the Cape Fear River.

TOPOGRAPHY OF THE COASTAL PLAIN

Within the area covered by the geologic map (pl. 1), the upland surface of the Coastal Plain is gently rolling, has broad interstream divides, and flat, wide valleys. The relief on this part of the Coastal Plain is less than that on the Piedmont plateau and Triassic lowland; the divides are more rolling, the valley sides are not as steep, and the valley bottoms are wider and flatter. Toward the southeast the relief increases as valleys become deeper; slopes are steeper and valleys are narrower where streams have eroded through the cover of Coastal Plain deposits into the underlying pre-Triassic crystalline rocks.

The highest altitudes in the mapped area are along the inner edge of the Coastal Plain at the top of the escarpment facing the Triassic trough. Carthage, at the top of this escarpment, has an altitude of about 580 feet and is the highest point in the vicinity of the Deep River coal field. Northeast of Carthage the altitude of the inner edge of the Coastal Plain ranges from 400 to almost 500 feet. Southeast from this edge the average altitude of the Coastal Plain decreases gradually but not uniformly. The surface of the Coastal Plain in this region does not show the same consistent southeastward decrease in altitude that is exhibited by the Piedmont plateau. Pratt (1917, p. 98) gives the following elevations of points in the Coastal Plain southeast of the Deep River field: Cameron (eastern Moore County), 300–312 feet; Vass (eastern Moore County), 317 feet; Southern Pines (southern Moore County), 400–519 feet.

SOURCES OF ALTITUDE DATA

Altitudes of points in the Deep River coal field and in the adjacent Piedmont plateau and Coastal Plain are shown on the geologic map (pl. 1). These altitudes are from the following sources:

1. Altitudes of bench marks and traverse stations were established by the U. S. Coast and Geodetic Survey (Braten and McCombs, 1938).
2. Altitudes of temporary bench marks and water surfaces along Deep River were established by Saville (1924, p. 11; pls. III, IV, and V).
3. Altitudes between the Gulf and the Carolina mine were established by plane table traverses during the field investigation for this report.
4. Other altitudes were established by an integrated network of aneroid traverses tied to bench marks. They are adjusted for diurnal temperature and pressure variations and are believed to be accurate within plus or minus 5 feet for the ground surface at the point where the altitude is shown on the map.

POPULATION AND SETTLEMENT

Most of the people in the Deep River region live on small farms of about 30 to 300 acres. In general, the Triassic lowland, as compared with the rest of the area described in this report, has the least cultivation, the fewest farms, and the lowest population per square mile, whereas the Coastal Plain has the most cultivation and the highest population per square mile. The populations of the Piedmont plateau and the Coastal Plain adjacent to the Deep River coal field are rather uniformly distributed, but the population of the Triassic lowland is somewhat concentrated in farms and small communities along the rivers and in the city of Sanford.

According to the 1950 census (U. S. Bureau of the Census, July 15, 1951, table 3, p. 3–7), the distribution of population in Chatham, Lee, and Moore Counties was as follows:

County	Land area (square miles)	Total population	Population per square mile
Chatham	707	25, 392	35. 9
Lee	255	23, 522	92. 2
Moore	672	33, 129	49. 3

Sanford is the largest community in the Deep River coal field. The populations of communities shown on the geologic map (pl. 1), as listed in the 1950 census, are as follows:

Sanford (Lee County seat)	10, 013
Carthage (Moore County seat)	1, 194
Merry Oaks	160
Haywood (Moncure)	169
Goldston	372

TRANSPORTATION

The Deep River coal field is served by five railroads; the Seaboard Air Line R. R. Co., Atlantic Coast Line R. R., Atlantic and Yadkin R. R., Atlantic and Western Ry. Co., and Norfolk Southern Ry. Co. (the route of this railroad closely follows the coal outcrop); by four federal highways, U. S. Highway 1, 15, 501, and 421, and by several state highways. Improved county roads, many of them paved, provide easy access to all parts of the field.

CLIMATE

The climate of central North Carolina is warm and humid. Annual temperatures in the vicinity of the Deep River coal field average about 60 F., and the annual precipitation averages about 45 inches. There is a considerable climatic contrast between summer and winter, however. In the summer, temperatures average about 77 F. and rainfall averages 4 to 6 inches per month, whereas in the winter, temperatures average about 43 F. and rainfall averages 2 to 4 inches per month. The temperate autumn, winter, and spring climate of this region has long been famous and is partly responsible for the growth of the resort communities of Pinehurst and Southern Pines, which are respectively 7 and 20 miles south of the coal field.

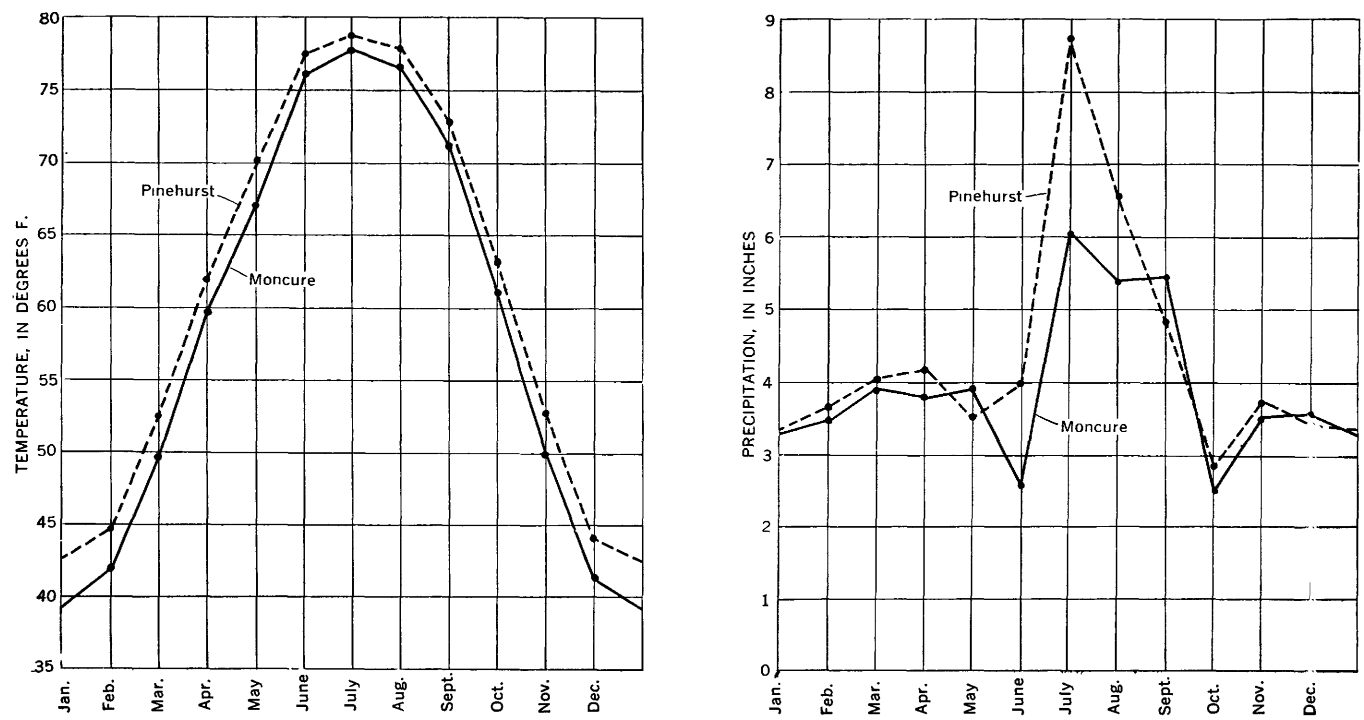
Weather stations have been maintained by the U. S. Weather Bureau for many years at Moncure, near the north end of the mapped area, and at Pinehurst, a few miles southwest of the mapped area. A compilation of records taken at these stations prior to 1931 and summarized by the Weather Bureau (Climatic summary of the United States, p. 9–10, 14–15) is given below in table 1.

Climatic data obtained at Moncure and Pinehurst since 1930 are contained in monthly reports published by the Weather Bureau (Climatologic data for the United States by sections, North Carolina section). Monthly averages for the period 1940–49 for these stations have been summarized in graphs (fig. 3). These graphs show that temperatures at Pinehurst average about 2° F higher than at Moncure, and that the precipitation is also somewhat higher at Pinehurst. During the 1940–49 period the average temperature was 59.1° F at Moncure and 61.5° F at Pinehurst; the annual precipitation averaged 47.53 inches at Moncure and 52.74 inches at Pinehurst.

TABLE 1.—*Climatic summary of temperature and precipitation at Weather Bureau stations at Moncure and Pinehurst*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Average monthly and annual precipitation													
Moncure [1]	3.29	3.90	3.73	3.45	3.65	4.30	5.05	4.90	3.59	2.71	2.22	3.30	44.09
Pinehurst [2]	3.36	3.83	3.58	3.31	3.55	4.82	5.82	5.35	3.86	2.83	1.84	3.35	45.55
Average monthly and annual maximum temperature													
Moncure [1]	54.0	55.2	64.8	72.6	80.9	87.1	89.6	88.3	83.4	73.8	63.6	54.1	72.3
Pinehurst [2]	54.8	56.8	65.7	74.4	81.9	87.8	90.2	88.9	84.4	74.9	63.9	54.8	73.0
Average monthly and annual minimum temperature													
Moncure [1]	29.8	30.3	38.6	45.2	45.5	63.3	67.1	66.1	60.6	47.5	36.5	30.3	47.5
Pinehurst [2]	32.7	33.6	41.0	47.8	56.1	64.1	68.0	67.0	61.7	49.8	39.2	33.5	49.5
Average monthly and annual average temperature													
Moncure [1]	41.9	42.8	51.7	58.9	67.7	75.2	78.3	77.2	72.0	60.0	50.0	42.2	59.9
Pinehurst [2]	43.8	45.1	53.3	61.1	69.0	75.9	79.1	77.9	73.3	62.3	51.6	43.9	61.4

[1] Records for 1894–1930, inclusive.
[2] Records for 1903–30, inclusive.



Average monthly temperature at Pinehurst and Moncure during the period 1940–1949

Average monthly precipitation at Pinehurst and Moncure during the period 1940–1949

FIGURE 3.—Monthly temperature and precipitation at Pinehurst and Moncure, 1940–49.

DRAINAGE AND WATER SUPPLY

STREAM SYSTEMS

The southern half of the Deep River Triassic basin lies entirely within the drainage system of the Cape Fear River. This river originates in the Triassic lowland, near Moncure, at the confluence of its two main tributaries, the Deep River and the Haw River.

From its sources in Guilford and Forsyth Counties, between Greensboro and Winston-Salem, the Deep River flows southeastward across the Piedmont plateau into northern Moore County, turns abruptly east about 10 miles west of Glendon (see map of lower Deep River, fig. 4), and enters the Triassic basin at Glendon. It flows about parallel to the coal outcrop across the northern part of the coal field, leaves the Triassic basin north of Sanford and re-enters it near Moncure, 3 miles above its junction with the Haw River. All of the Triassic basin west of Sanford (here called the Sanford basin) and adjacent parts of the Piedmont Upland are drained by the Deep River and its tributaries. Within the Sanford basin the more important tributaries are McLendons Creek and Governors Creek, both in Moore County; and Big Pocket Creek, Little Pocket Creek, Pattersons Creek, Buffalo Creek, and Little Buffalo Creek, all in Lee County. The drainage area of the Deep River above Moncure is about 1,410 square miles, of which about one-fifth is in the Triassic (Sanford) basin; its total fall exceeds 800 feet.

The Haw River originates in Guilford and Rockingham Counties, flows almost directly southeastward across the Piedmont plateau and enters the Triassic lowland 2 miles north of Moncure. Tributaries of this river drain the western part of the Durham basin and adjacent portions of the Piedmont Upland. The drainage area of the Haw River above Moncure covers about 1,800 square miles—about one-seventh is in the Triassic (Durham) basin—and it has a total fall of more than 800 feet.

An important drainage divide is formed by the inner edge of the Coastal Plain along the southeast edge of the Deep River field. This divide is breached, in this region, only by the Cape Fear River through its water gap at Buckhorn Dam (see pl. 4). Northwest of this divide, the Sanford basin is drained by streams flowing northward to the Deep River; the Colon cross structure is drained mainly by Lick Creek and its tributaries, which flow northeastward to the Cape Fear River; and the southwest end of the Durham basin is drained by Buckhorn, Gulf, and Shaddox Creeks, which flow southwestward to the Cape Fear River. Southeast of this drainage divide, the Coastal Plain is drained by southeastward-flowing streams; most of these streams are branches of the Little River, which is a tributary of the Cape Fear River.

STREAM DISCHARGE

The discharge of the Deep, Haw, and Cape Fear Rivers has been recorded by the U. S. Geological Survey at the following gaging stations: On the Deep River at Ramseur, about 25 miles northwest of Glendon, and at Moncure; on the Haw River, about 6 miles north of Moncure and 5 miles east of Pittsboro, and on the Cape Fear River at Lillington, about 20 miles southeast of Moncure. The mean discharges of the rivers at these stations for the years 1935–45 and the maximum and minimum daily discharges for the years 1940–45 are summarized in table 2.

A record of discharges for both the Deep and Haw Rivers at Moncure is available for the year 1899, and a record of the flow of Deep River at Cumnock was made in 1901. For comparison, these figures[3] are included in table 2.

The average discharges of the Deep, Haw, and Cape Fear Rivers during years of record maintenance are as follows:

Average discharge of the Deep, Haw, and Cape Fear Rivers, in cfs, for total period of observations

Deep River at Ramseur (1923–48)	348
Deep River at Moncure (1930–48)	1,392
Haw River near Pittsboro (1929–48)	1,267
Cape Fear River at Lillington (1924–48)	3,331

The maximum flood discharge recorded at the Pittsboro gaging station was 79,000 cfs (Haw River); at the Moncure station, 27,000 cfs (Deep River); and at the Lillington station, 192,000 cfs (Cape Fear River). The minimum daily discharge recorded at the Pittsboro station was 9 cfs; at Moncure, 9.5 cfs; and at Lillington, 29 cfs. Records show that the discharges of the rivers are irregular from year to year, although the maxima usually occur in the late winter or early spring months, and the minima occur in the fall months.

Flooding is a common occurrence along the Deep River in the Triassic lowland because here the gradient is considerably lower than it is upstream in the Piedmont upland (see profile, fig. 4). Flooding was responsible for the final closing of the Cumnock mine, whose portals penetrate one of the low river terraces.

[3] Sources of data on stream-flow measurements listed in this report are as follows:

Data for 1899 and 1901: Saville, Thorndike, and Smith, 1925, Discharge records of North Carolina streams, 1889–1923: North Carolina Dept. Cons. and Devel. Bull. 34, p. 50–52, 57–60.

Data for 1935–48: Johnson, T. S., and Mann, C. L. Jr., Discharge records of North Carolina streams, 1889–1936: North Carolina Dept. Cons. and Devel. Bull. 39, p. 72, 74, 75 (1936). U. S. Geol. Survey Water-Supply Papers 802 (1936), 822 (1937), 852 (1938), 872 (1939), 892 (1940), 922 (1941), 972 (1943), 1002 (1944), 1022 and 1032 (1945), 1052 (1946), 1082 (1947), and 1112 (1948).

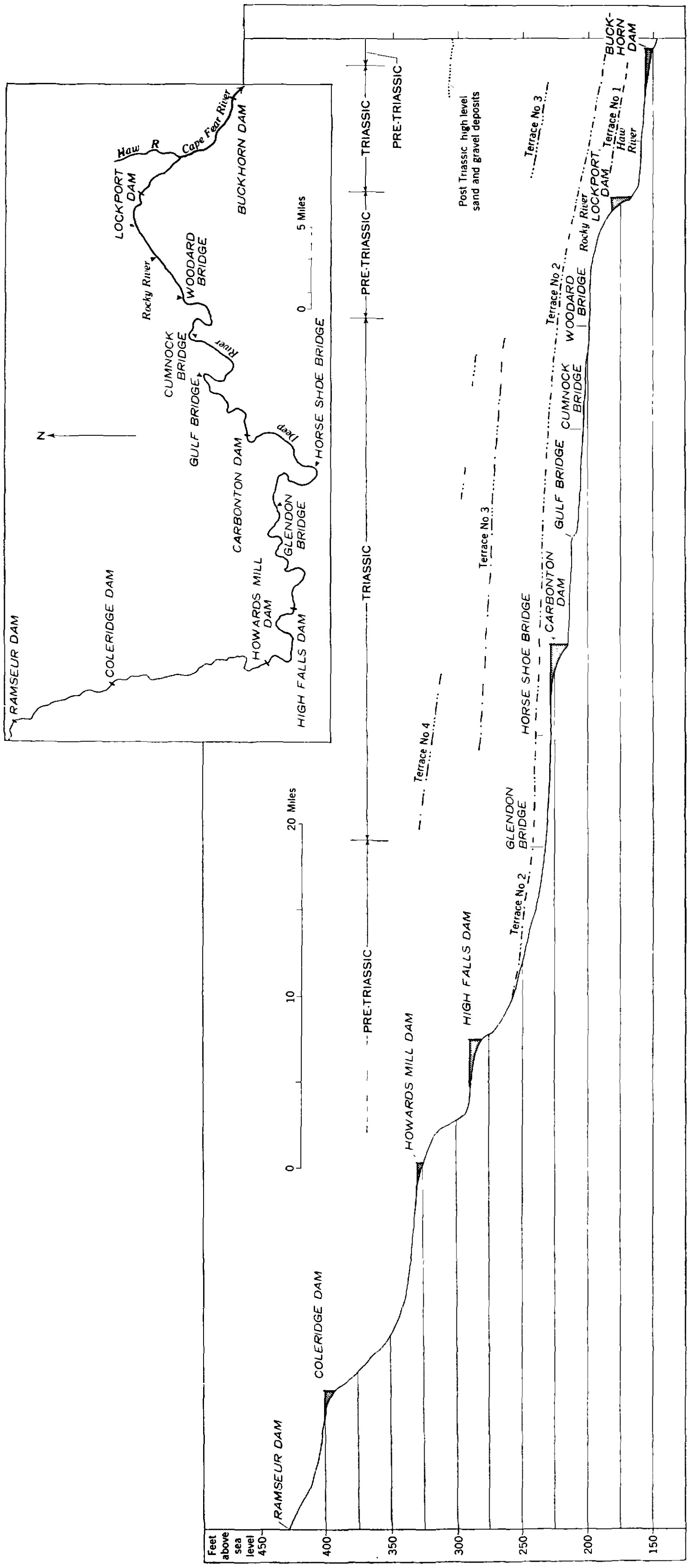


FIGURE 4.—Map and profile of Deep River and Cape Fear River from Ramseur to Buckhorn Dam, showing profiles of river terraces.

TABLE 2.—*Stream flow measurements for calendar years, 1899, 1901, and 1935–45*

[Mean discharge in cfs]

Year	Stations on Deep River			Stations on Haw River		Station on Cape Fear River
	At Ramseur (346 sq mi)	At Cumnock (1,110 sq mi)	At Moncure (1,410 sq mi)	Near Pittsboro (1,310 sq mi)	At Moncure (1,800 sq mi)	At Lillington (3,440 sq mi)
1945	453			1,725		5,014
1944	444		[1] 1,657	1,650		4,536
1943	311			1,186		3,145
1942	227			936		2,395
1941	165		734	674		1,820
1940	338		969	1,190		2,524
1939	397		1,557	1,529		3,935
1938	265		916	1,087		2,490
1937	425		1,435	1,733		3,830
1936	595		2,514	2,240		5,863
1935	312		1,304	1,198		3,012
1901		1,763				
1899			2,519		2,590	

Maximum and minimum daily discharges during the year

Year	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1945	27,800	14					76,500	84			185,000	128
1944	14,000	16					28,000	25			56,000	106
1943	4,190	10					13,800	42			36,200	81
1942	5,330	1.7					12,000	31			25,900	130
1941	2,480	0.7			12,300	9.5	8,700	19			23,600	37
1940	6,480	3			12,000	17	18,700	24			28,100	62

[1] Discharge record for period October 1, 1943–September 30, 1944.

Precautions against floods should be taken where mine openings are near the Deep River.

Flow characteristics of the Deep and Haw Rivers are very similar—indicated by the yearly mean discharge figures listed above. A further indication of this similarity is offered by the monthly discharge record at Moncure during 1899; this is the only year for which similar flow measurements have been made near the mouths of both of these two streams (see table 3 below).

TABLE 3.—*Mean discharges of Deep River and Haw River at Moncure during 1899*

[In cfs]

Month	Deep River	Haw River	Month	Deep River	Haw River
January	2,900	2,840	August	638	856
February	10,100	9,860	September	378	465
March	7,560	7,816	October	873	1,028
April	3,250	2,790	November	911	1,116
May	1,730	1,881	December	571	464
June	633	944			
July	687	1,019	Total for year	2,519	2,590

Although the abundant, rather uniformly distributed rainfall is favorable to permanent flow, tributary streams of the Deep, Haw, and Cape Fear Rivers reflect differences in flow, depending on their physiographic location and the geology of their drainage areas. In the Triassic lowland most streams have a fairly constant and continuous flow, which results in part, from abundant springs and low gradients. In the Piedmont Upland bordering the Triassic, only the larger streams are permanent, and their flow is less regular. In the Coastal Plain the smaller tributaries are likely to be dry, except after rains, because their drainage areas are small, and because a part of the water entering the ground passes down the dip beneath confining beds and does not reach the streams.

CHEMICAL QUALITY OF RIVER WATER

River waters in the vicinity of the Deep River field are, with a minimum of treatment, chemically suitable for most industrial uses. Data compiled by Ray and Randolph (1928, p. 58–59) show that most North Carolina streams are low in dissolved solids and in hardness, as compared with streams in the industrial areas of the North and Midwest. Available analyses of the river waters in the vicinity of the Deep River field are summarized in table 4 below. They indicate that the Deep, Haw, and Cape Fear Rivers have a hardness similar to the average North Carolina stream, but that these rivers are somewhat higher in total dissolved solids. They are generally lower in iron, but they are higher in magnesium, sodium, and potassium. The Deep River has more suspended matter than most streams in North Carolina; the Haw River has less. Analyses of waters from the Little River, a few miles southeast of Sanford, show that this stream in the Coastal Plain has only about half as large a content of dissolved solids as the Deep and Haw Rivers in the Piedmont and Triassic.

TABLE 4.—*Analyses of surface waters in and near the Deep River coal field*

[In parts per million, except color and pH]

Location of sample	Date	Suspended matter	Color	pH	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solid	Hardness as $CaCO_3$
Deep River at Ramseur [1]	1946-47 [2]	41	20	6.85	14.0	0.04	7.4	2.9	15.0	41	7.1	15.0	0.1	1.4	91	30
Do.[3]	Nov. 2, 1944	10	44		16.0	.05	6.0	2.6	7.6	31	6.9	5.8	0	1.8	74	26
McLendons Creek near Carthage.[4]	Aug. 11, 1949		17	6.1	6.9	.05	2.6	1.0	0	6	2.1	2.2	.1	.3	29	11
Deep River at Highway 421.[5]	June 30, 1927	50	20		12.0	.4	3.1	.9	3.7	14	3.7	3.1		.8	44	11
Deep River at Highway 15.[5]	Jan. 11, 1926	30	8		15.0	.35	5.5	.8	3.6	22	2.8	2.3		.2	52	17
Deep River at Moncure [6]	1943-44 [2]	49	25		9.0	.06	4.4	1.9	7.6	24	4.9	6.9	0	.6	55	19
Do.[1]	Mar. 20, 1947		20	7.05	9.3	.03	3.8	1.8	6.8	21	6.3	5.2	0.1	.3	49	17
Haw River near Pittsboro.[3]	Oct. 19, 1944	6	17		16.0	.02	5.8	2.4	21.0	54	9.5	11.0	.3	.3	95	24
Do.[4]	Apr. 20, 1949		6	6.8	14.0	.02	5.6	.4	10.0	30	6.0	3.9	.3	.6	57	16
Do.[1]	Mar. 20, 1947		15	7.6	12.0	.02	4.5	2.1	8.3	29	6.4	4.8	.3	.4	54	20
Haw River near Moncure.[7]	Oct. 11, 1945	11	24	6.7	15.0	.03	6.6	2.7	11.0	37	8.6	7.1	.3	2.0	80	28
Cape Fear River below Carolina Power Co. plant.[5]	1927 (?)	50	12		9.5	.32	5.1	.9	5.4	26	2.0	3.0		.15	53	16
Little River at Vass [8]	Aug. 30, 1948	2	22	5.8	4.6	.27	.8	.4	3.0	6	1.5	2.5	0	.3	27	4
Upper Little River near Lillington.[1]	Mar. 20, 1947		30	6.2	5.3	.02	1.8	.9	3.6	9	3.0	3.9	0	.2	32	8

[1] Lamar, W. L., and Joyner, B. F., 1946–47, Chemical character of surface waters of North Carolina: North Carolina Dept. Cons. and Devel., Div. Water Res. and Eng. Bull. 52, v. 3, p. 28, 1949.

[2] Composite of daily samples for water-year Oct. 1–Sept. 30.

[3] Lamar, W. L., 1944–45, Chemical character of surface waters of North Carolina: North Carolina Dept. Cons. and Devel., Div. Water Res. and Eng. Bull. 52, v. 1, pp. 12, 14, 1947.

[4] Pauszek, F. H., 1948–49, Chemical character of surface waters of North Carolina: North Carolina Dept. Cons. and Devel., Div. Water Res. and Eng. Bull. 52, v. 5, p. 46, 1950.

[5] Ray, C. E., Jr., and Randolph, E. E., Chemical quality of the surface waters of North Carolina with relation to industrial use: North Carolina Dept. Cons. and Devel., Econ. paper 61, table 4, pp. 36–39, table 6, pp. 46–47, 1928.

[6] U. S. Geol. Survey, Water Resources Br., Quality of surface waters of the United States, 1944: Water Supply Paper 1022, p. 49, 1947.

[7] Lamar, W. L., 1945–46, Chemical character of surface waters of North Carolina: North Carolina Dept. Cons. and Devel., Div. Water Res. and Eng. Bull. 52, v. 2, p 24, 1948.

[8] Pauszek, F. H., and Joyner, B. F., 1947–48, Chemical character of surface waters of North Carolina: North Carolina Dept. Cons. and Devel., Div. Water Res. and Eng. Bull. 52, v. 4, p. 26, 1949.

SPRINGS AND WELLS

Springs are exceedingly abundant throughout the Deep River Triassic basin, but are less common in the adjacent Piedmont plateau and Coastal Plain. They occur in four principal locations: along contacts of diabase and granite intrusives; along outcrops of the bottoms of sandstone and conglomerate beds, where such beds overlie less permeable strata; along the edges of river terrace deposits, and along the bottom of the sand and gravel (Pliocene?) deposits at the inner edge of the Coastal Plain; and along faults or joints.

Springs are numerous along most streams in the Deep River coal field and are responsible for the permanent flow of many streams. They are important sources of domestic water supply in the rural areas; almost every farm in the Deep River field has one or more springs serving its water needs. The locations of all springs mapped during the field investigations are shown on the geologic map (pl. 1).

Where springs or streams are not close at hand, an adequate domestic supply of water can usually be obtained by drilling wells. In the Coastal Plain southeast of the Deep River field, Stephenson and Johnson (1912, p. 434) report that ample supplies of water are obtainable from wells 10 to 60 feet deep dug in the permeable sand and gravel deposits. In the Piedmont, wells penetrating the crystalline rocks usually obtain water within 100 feet of the surface; the water is derived from openings along the abundant cleavage surfaces and joints in the rocks. Within the Triassic basin, however, the supply of subsurface water is extremely variable, and wells must be located with great care. Because of the existence of thick, impermeable beds of siltstone and claystone it is possible to drill to depths of several hundred feet in some areas without obtaining an adequate supply of water. Coarser-grained strata (conglomerate and sandstone) are better aquifers, although the porosity, permeability, and water yield may be relatively low because of the poor sorting of the sediments.

The average yield of five wells drilled in the Deep River basin is reported to be only 10 gallons per minute (Hydrologic data on the Cape Fear River basin, p. 139). The yield may be much greater where the rocks are cut by faults or dikes, however, and therefore it is desirable to drill wells near such structures wherever possible. The geologic map (pl. 1) shows the locations of faults and dikes as well as the outcrops of the main conglomerate beds, most of which are probably water bearing. Wells drilled in the terrace deposits, also shown on plate 1, generally obtain moderate to large water supplies.

INDUSTRIAL AND DOMESTIC WATER USE

The quality and abundance of its river waters, together with the nearby reserves of coal, make the Deep River coal field a favorable site for the production of hydroelectric and steam power and for the development of other industries requiring these resources. In 1950, the Carolina Power and Light Company was the only industrial user of river water in the Deep River coal field. It operates a large steam-power plant on the Cape Fear River, 3 miles south of Moncure, as well as small hydroelectric plants at Buckhorn, Lockport, and Carbonton. Several small textile mills, which develop their own hydroelectric power, are located on the upper Deep and Haw Rivers. The power potential of the Deep River has been surveyed by Saville (1924, p. 7) who estimated that 90 percent of the total fall of the river could be utilized to produce hydroelectric power.

Water for agricultural and domestic use by the rural population is amply provided by springs, streams, wells, and artificial lakes constructed to catch water for livestock. Most of the communities rely on wells, although Sanford utilizes the headwaters of Lick Creek (where it has two reservoirs), a filtration plant, 2 miles east of the city, and a third (auxiliary) reservoir, known as Lake Williams, 4 miles east of the city. Carthage obtains its water from wells and from springs along the base of the gravel deposits underlying the town.

VEGETATION AND LAND USE

Vegetation and land use differ somewhat in the three physiographic divisions of the Deep River region. These differences primarily reflect the soil differences, and thus indirectly reflect differences in drainage, landscape age, and bedrock lithology.

Within the Triassic lowland, according to Ashe (1897, p. 192) the original forest consisted of "* * * an upper dominant story of short-leaf pine from 50 to 70 feet in height, with an underwood of post oak, Spanish oak, black-jack oak, white oak, and white hickory."

Most of this original forest has been destroyed, but the second-growth timber consists mainly of the same types with a scattering of maple, dogwood, cedar, and poplar; cedar is most abundant along the outcrops of Triassic diabase intrusives. Considerably more than half of the Triassic lowland is forested; lumbering is an important occupation, and mine operators have an adequate supply of timber close at hand. The cultivated areas are planted in tobacco, cotton, grains, pasture, and vegetables. Practically all the stream terraces are under cultivation; they provide some of the best agricultural land in the region.

The Piedmont Upland west of the Triassic lowland originally had a forest cover similar to that on the Triassic, although the broad-leaf trees were somewhat shorter according to Ashe (1897, p. 195). In general, the present forests (which are almost entirely second-growth) seem to have a higher proportion of the oaks and a lower proportion of pine than the forests of the Triassic belt. The proportion of land under cultivation is higher in the Piedmont; corn, wheat, hay, cotton, tobacco, and vegetables are the principal crops.

The much dissected granitic and metamorphic belt bordering the southeast edge of the Triassic northeast of Sanford is covered with a forest consisting principally of oak; this area is not extensively cultivated.

That portion of the Coastal Plain south and east of the Deep River field lies within an area called the "Pine barrens" by Ashe (1897, p. 152–156). He reports an original growth of long-leaf pine with scattered scrub oaks, including the fork-leaf oak, barren willow oak, black-jack oak, and post oak. The long-leaf pine has gradually disappeared from this area and has been replaced by the short-leaf pine. Because of the sandy, clay-impoverished soil, the forest cover was probably never very thick in this part of the Coastal Plain. Aided by soil-building ingredients, extensive parts of this area are now being cultivated, and there are few large forest plots. Tobacco, cotton, corn, peaches, berries, and vegetables are the main crops.

GEOLOGIC FORMATIONS

GENERAL STATEMENT

The Deep River Triassic basin, which includes the Deep River coal field, is a wedge-shaped block of Triassic sedimentary rocks. Metamorphosed pre-Cambrian, or Paleozoic, igneous and sedimentary rocks underlie this Triassic sedimentary wedge and border it on both sides. These pre-Triassic metamorphic rocks are intruded by late Paleozoic granites, and both the Triassic and pre-Triassic rocks of the region are cut by late Triassic, or possibly Jurassic, basic dikes. High-level surficial deposits, possibly of Pliocene age, overlie the Triassic and pre-Triassic rocks along the southeast side of the Deep River basin, and Pleistocene and Recent terrace deposits are present along the main streams, particularly within the Triassic belt.

This report is concerned mainly with the Deep River coals and associated Triassic sedimentary rocks in the area covered by the geologic map (pl. 1), but brief descriptions of the pre-Triassic and post-Triassic rocks are also presented to provide a more complete picture of the geology of the Deep River coal field and adjacent territory.

PRE-TRIASSIC ROCKS

GENERAL DESCRIPTION

Pre-Triassic metamorphic rocks on the northwest side of the Deep River Triassic basin consist of slate, quartzite, conglomerate, acid tuff, rhyolite flows, andesite flows and tuff, and volcanic breccia. These rocks underlie a strip of territory, 10 to 50 miles wide, that extends northeastward across North Carolina and is commonly called the "Carolina Slate Belt." The territory northwest of the Deep River basin, shown on the geologic map (pl. 1), is part of the "Carolina Slate Belt" and is almost entirely occupied by such rocks, but the different lithologic units are not differentiated on this map. Similar rocks are also exposed southeast of the Deep River basin where the post-Triassic deposits have been stripped off.

The eastern side of the Durham basin, northeast of the area shown on the geologic map, is bordered for about 15 miles by a belt of pre-Triassic mica-gneiss, and micaceous, chloritic, and graphitic schist. This belt, which is 5 to 10 miles wide, emerges from beneath the Coastal Plain cover southeast of the Durham basin and extends northeastward into Virginia. It does not enter the area shown on plate 1, but small patches of similar gneiss and schist are present in the pre-Triassic rocks on the southeastern side of the Deep River basin within the mapped area. This belt of gneiss and schist is identified as the Wissahickon schist on the geologic map of the United States (Stose and Ljungstedt, 1936) and on the geologic map of North Carolina (1937).

Metamorphic rocks of both the "Carolina Slate Belt" and the Wissahickon schist belt are intruded by relatively unmetamorphosed granite. A belt of granite, which extends from northern Chatham County into southern Virginia, borders the western side of the Durham basin. Other belts of granite are present east of the Durham basin. Small granite intrusives, which are present along the southeastern side of the Colon cross structure and Durham basin within the mapped area, are shown on plate 1. The age of these granite intrusives is generally regarded as Paleozoic, probably Carboniferous.

Debris from the metamorphosed volcanic and sedimentary rocks of the "Carolina Slate Belt," from the gneiss and schist of the Wissahickon schist belt, and from the granite intrusives near the Deep River Triassic basin, is present in the Triassic sediments of the Deep River coal field. It is pertinent, therefore, to briefly review the general characteristics of these pre-Triassic rocks, even though no attempt has been made to study or map them in detail.

PRE-TRIASSIC METAMORPHIC ROCKS

PREVIOUS DESCRIPTION

A general description of the pre-Triassic metamorphic rocks of the "Carolina Slate Belt" was made by Emmons (1856, p. 41–72). Detailed descriptions of rocks in parts of this belt, not adjacent to the Deep River Triassic basin, have subsequently been made by several other geologists; however, the only detailed investigation of the metamorphic rocks within the area covered by the geologic map (pl. 1) was made by Stuckey (1928) during a study of the pyrophyllite deposits northwest of the Sanford basin. Stuckey's report contains a geologic map showing the distribution of lithologic units in the metamorphic belt bordering the Triassic basin west of Carbonton. The origin of the slates in the "Carolina Slate Belt" was discussed by Alexander (1932).

Little attention has been given to the Wissahickon schist belt east of the Deep River basin. A report by Harrington (1947) briefly describes the graphitic schists in this belt near Raleigh.

LITHOLOGY AND DISTRIBUTION

The lithology of rocks in the "Carolina Slate Belt" along the western side of the Deep River basin has been summarized by Stuckey (1928, p. 16–17) as follows:

> The rocks of the area, because of the complex character and well defined cleavage, have been called "slates"; but the name is misleading and confusing. They consist of volcanic-sedimentary formations made up of slates and tuffs with which are long interbedded bands and lenses of volcanic breccia, flows and ash. There are two distinct types of tuffs, breccias and flows: one is acid and the other a more basic phase. The acid phase consists of fine and coarse tuffs, and breccias chiefly of a rhyolitic and dacitic character, with flows of rhyolite and dacite. In the basic phase the breccia and flow types are more common than the fine and coarse tuffs, but the latter are usually present in at least small amounts. Diabase dikes doubtless of Triassic Age cut the other formations.
>
> The formations seem to represent a period of continuous deposition during which the series was built up without break or unconformity. The tuffs are the most abundant rocks of the area and are looked upon as the controlling formation; the other formations, with the exception of the slate, occurring as concordant flows or interbedded with them. The slate is considered as the youngest formation in the series, having been formed at the close of the period of volcanic activity and hence grades directly into the fine tuff * * *.
>
> Metamorphism has been so complete that shales have become slates and the tuffs, flows and breccias have been so sheared that it is difficult to tell in the field which is slate, tuff, or flow. Hence they have all been called "slates." The series has been mashed and bent into folds and the original bedding planes have been largely destroyed by a well defined cleavage which dips from 45 degrees to 85 degrees to the northwest. The strike of the cleavage planes, axes of folding and different formations are all practically parallel and vary from N. 65 degrees E. to N. 30 degrees E.

Acid tuff underlies more than half of the area northwest of the Triassic basin shown on plate 1. It consists typically of fragments of quartz, orthoclase, and acid plagioclase feldspars embedded in an aphanitic greenish or bluish groundmass. Thin sections examined by Stuckey contain patches of hematite and limonite, small grains of titanite and apatite, and the secondary minerals kaolinite, chlorite, epidote, and calcite. Fragments of tuff in the Triassic sediments that have been examined microscopically have substantially the same mineralogy. The acid tuff is light to dark greenish-, pinkish-, or brownish-gray. Most tuff in this area is highly schistose, but a few exposures of relatively unmetamorphosed massive tuff have been observed, and in these exposures the tuff bears a strong resemblance to some sandstones in the basal Triassic sediments, which are composed of tuffaceous debris.

Rhyolite flows are present northwest of the Deep River basin; the largest flow, about 3 miles long, is near the pyrophyllite deposits northwest of Glendon. These rocks are mineralogically similar to the acid tuff; they grade laterally into the tuff, and resemble finer phases of the tuff.

Andesite flows and tuff are extensively distributed west of the mapped area, but andesitic rocks probably underlie little of the metamorphic belt in the area covered by plate 1. A patch of andesite tuff, less than half a mile long, is present near the Triassic border southeast of Goldston. A dike of probable andesitic composition crops out 1 mile northeast of Woodard Bridge.

Volcanic breccia occupies narrow bands and lenticular patches probably covering about a tenth of the area shown on plate 1 northwest of the Triassic basin. In part, this is brecciated acid tuff or rhyolite, and in part, it is brecciated andesite; locally, the breccia is limonitic.

Slate underlies about a third of the territory northwest of the Deep River basin shown on plate 1. The largest slate belt in this area extends from McConnell east to the border of the Triassic near Glendon. The slate is well exposed in a new road cut at the south end of the bridge across Deep River near Glendon, where the bedding of the slate dips gently westward and the cleavage dips steeply westward. It is light to dark gray, locally greenish or brownish. Brown and red bands resembling varves are present in some places. The slate consists of quartz and feldspar grains in a mottled sub-microscopic groundmass containing considerable sericite.

Lenses of conglomerate are present near the Triassic border along the north side of the Colon cross structure. They have been noted along U. S. Highway 1 and along the Triassic border northeast of the Lee Brick and Tile Company plant. These rocks are composed of debris from the pre-Triassic igneous rocks. Small patches of quartzite have also been observed in this area.

Lenticular masses of pyrophyllite are present in the acid tuff and acid volcanic breccia northwest of the Deep River basin. These pyrophyllite lenses, which have been described in detail by Stuckey (1928, p. 26–58), grade laterally into the acid volcanic rocks. Most of the commercially important pyrophyllite deposits are in a belt about a mile west of the Triassic border; mines opened in these deposits are shown on the geologic map (pl. 1). The pyrophyllite-bearing rocks are generally schistose.

Pre-Triassic metamorphic rocks exposed southeast of the Deep River basin, within the area covered by plate 1, include all of the rock types present northwest of the basin, as well as small patches of chloritic and micaceous schist and gneiss typical of the Wissahickon schist belt east of the mapped area. This schist and gneiss is characterized by an abundance of chlorite and muscovite—in contrast to the other metamorphic rocks in the mapped area, which are relatively deficient in chlorite and muscovite.

ORIGIN

It is now generally recognized that the rocks of the "Carolina Slate Belt" are, in part, metamorphosed igneous extrusive rocks and, in part, metamorphosed sedimentary deposits. The slate has been regarded by most workers as a shallow-water estuarine deposit composed of land-waste from nearby acid volcanic rocks. According to Alexander (1932, p. 20), the banding that occurs in some slates is evidence of seasonal variations in sedimentation. The chloritic and micaceous schist and gneiss east of the Deep River Triassic basin are believed to be metamorphosed sediments and igneous intrusions.

AGE

Age of the rocks in both the "Carolina Slate Belt" and the Wissahickon schist belt is listed as pre-Cambrian on the geologic map of North Carolina and on the geologic map of the United States. On the geologic map of North America (Stose, 1946) the rocks of the "Carolina Slate Belt" are listed as Paleozoic, and those included in the Wissahickon schist belt are listed as pre-Cambrian. No definite indication of the age of these rocks has been observed in the area covered by this report.

CARBONIFEROUS(?) GRANITE

FORM AND DISTRIBUTION OF INTRUSIVES

Granite intrusives crop out in four irregular areas along the southeastern side of the Deep River basin within the territory covered by the geologic map (pl. 1). The largest of these intrusives lies along the Triassic border northeast of Salem Church in eastern Lee County, crosses the Cape Fear River at Buckhorn Dam, underlies a large area southeast of Corinth, and extends beyond the eastern limit of the mapped area. Granite occupies a small area near the Sanford water works, and granite intrusives also crop out northeast of Lemon Springs and west of U. S. Highway 1 in southern Lee County—here, they have been partly exposed by erosion of the overlying post-Triassic surficial deposits. A small patch of granite was mapped near the Triassic border northwest of Moncure.

In general, these granite intrusives follow the northeasterly trend of the cleavage or schistosity of the pre-Triassic metamorphic rocks, but some intrusive contacts are highly irregular. Commonly, the granite masses finger-out into the adjacent schist, locally forming injection gneiss. Such gneiss is well exposed along the Triassic border north of the Sanford water works. Lenticular inclusions of metamorphic rocks are present near the margins of the intrusives.

PREVIOUS DESCRIPTION

The granite intrusives near the Deep River coal field have not previously been mapped, although their existence was noted by Campbell and Kimball (1923, p. 44). No detailed information on any of the granite masses bordering the Deep River basin has been published, but Parker (1937) has briefly described a similar granite intrusion east of the Durham basin in Wake County.

PETROGRAPHY

The granite within the mapped area consists mainly of orthoclase, plagioclase (Ab_{10} to Ab_8An_2), and quartz. It contains small amounts of muscovite, chlorite, biotite, and hypersthene, and scattered grains of pyrite, epidote, apatite, titanite, and tourmaline. The feldspar grains are commonly speckled with inclusions of most of the accessory minerals, but the quartz grains contain few inclusions. Plagioclase grains commonly show crystal outlines; orthoclase and quartz do not. Almost all of the quartz grains have undulatory extinction. Thin sections of the granitic intrusive near the Sanford water works show the following percentage distribution of minerals: orthoclase, 35 percent; plagioclase, 41 percent; quartz, 15 percent; and accessory minerals, 9 percent. Thin sections of the intrusive northeast of Salem Church show the following mineral content: orthoclase, 49 percent; plagioclase, 13 percent; quartz, 32 percent; and accessory minerals, 6 percent.

This rock is generally unmetamorphosed, and the grains are randomly oriented, but near the edges of the intrusives the parallel orientation of grains and inclusions has produced platy flow structure. Platy structures noted in mapping are shown on plate 1. The granite is usually equigranular, few grains exceed 5 mm in diameter, and it is dominantly pinkish-gray.

Patches of dark greenish-gray gneissic granite are associated with the granitic intrusive northeast of Salem Church. Masses of this dark gneissic granite each of Buckhorn Dam are intruded by the normal granite, and the contacts between the two granites are sharp. Conspicuous belts of gneissic granite at the western end of Buckhorn Dam, however, grade laterally into the normal granite. Thin sections show that although the gneissic granite is mineralogically similar to the normal granite, it contains a higher percentage of the accessory minerals, particularly biotite, chlorite, and hypersthene, and the feldspars in the gneissic rock are so heavily loaded with inclusions—mainly of muscovite and apatite—that they are difficult to identify. In some gneissic granite the feldspar grains are relatively undeformed and are separated by narrow, sinuous bands composed of mosaic quartz lenses, stringers of hypersthene grains and shreds of biotite, chlorite, and muscovite. In other gneissic granite the feldspars are sheared, reoriented, and partly comminuted, and the other minerals are arranged in subparallel bands.

White quartz veins, ranging in width from a fraction of an inch to several tens of feet, cut both the granite and the pre-Triassic metamorphic rocks near the Deep River basin. These veins are particularly abundant near the Sanford water works (where they have been prospected for gold) and west of Moncure (where they have been mined for copper). The quartz veins probably are genetically related to the granite.

ORIGIN

The problems of the origin of the granite, whether by magmatic intrusions or by granitization, and the genetic relationship between the normal and the gneissic granite bordering the Deep River coal field are beyond the scope of this report. A more detailed study of these rocks would be desirable as a part of a study of the mineralogy, structure, and origin of all the granite intrusives near the Deep River basin.

AGE

Granite intrusives within the mapped area are younger than the pre-Triassic metamorphic rocks, some of which may be as young as early Paleozoic. These intrusives, together with the other granites of central North Carolina, have been regarded as Paleozoic, probably Carboniferous, and they are so listed on the geologic map of North America and on the geologic map of North Carolina. No definite age can be assigned to these intrusives on the basis of evidence now available.

TRIASSIC SEDIMENTARY ROCKS

GENERAL DESCRIPTION

The Triassic sedimentary rocks of the Deep River basin are clastic deposits, which consist of claystone, shale, siltstone, sandstone, conglomerate, and fanglomerate. The deposits are characterized by abrupt lateral changes in texture and composition. In some parts of the basin, the coarser sediments predominate, elsewhere the finer-grained sediments are most extensive. Lithologic units are generally no more than a few feet thick. About three-fourths of the rocks are red, brown, or purple; the rest are gray or black. Coal beds, which underlie about a fifth of the entire basin and about a third of the area described in this report, are generally less than 4 feet thick, constitute less than 0.05 percent of the Triassic deposits in the basin, and are characterized by abrupt lateral changes in thickness, rank, and quality.

The sediments in the Deep River basin are composed mainly of debris eroded from the nearby pre-Triassic metamorphic rocks; locally, they contain large amounts of debris eroded from the nearby Carboniferous (?) granite intrusives. These sediments were deposited as alluvial fans, as stream-channel and flood-plain deposits, and as lake and swamp deposits. In color and texture, the Deep River sediments are similar to those in most other Triassic basins of eastern North America, but in mineral composition these sediments are unique because of the peculiar mineralogy of the rocks from which they were derived.

Sediments in the Deep River basin were listed as partly Permian and partly Triassic by Emmons (1856, p. 277–282), but later studies of the flora by Fontaine showed that these rocks are not older than Upper Triassic and that they may be partly Lower Jurassic. The Deep River sedimentary rocks are now generally assigned to the Upper Triassic Newark group—a term first used by Redfield (1856, p. 357) and redefined by Russell (1892, p. 15), who included within it the sedimentary rocks of all the eastern Triassic basins.

TERMINOLOGY

Previous descriptions of the Triassic rocks in the Deep River basin have used the terms "shale" and "claystone" indiscriminately and have used the terms "siltstone," "sandstone," "conglomerate," and "fanglomerate" rather loosely. In order to convey more precisely the lithologic character of the Deep River Triassic, definitions of these terms as used in this report are listed below.

Claystone: A nongritty, nonlaminated rock revealing little or no fissility or bedding after prolonged weathering, composed dominantly of particles less than 1/256 mm in diameter. Most of the rocks in the Deep River basin previously listed as shales are claystones.

Shale: A nongritty, laminated or nonlaminated rock possessing definite fissility or bedding, composed dominantly of particles less than 1/256 mm in diameter.

Siltstone: A gritty, laminated or nonlaminated rock composed dominantly of particles between 1/256 mm and 1/16 mm in diameter. Generally harder than claystone or shale. Red or brown siltstone is usually darker than red or brown claystone and shale; gray siltstone is usually lighter than gray claystone or shale.

Sandstone: Any rock composed dominantly of grains between 1/16 mm and 2 mm in diameter. A "conglomeratic" or "pebbly" sandstone is one in which a tenth or more of the rock consists of grains more than 2 mm in diameter; a "silty" or "clayey" sandstone is one in which a tenth or more of the rock consists of particles less than 1/16 mm in diameter.

Conglomerate: A rock at least a fourth of which consists of fragments 2 mm in diameter or larger; fragments mostly rounded, subrounded, or subangular. Conglomerate beds are shown on the geologic map (pl. 1).

Fanglomerate: A rock at least a fourth of which consists of rock fragments 8 cm in diameter or larger; fragments mostly angular or subangular. Fanglomerate shown on plate 1 locally includes lenses of sandstone and conglomerate. This rock might be called very coarse conglomerate or sedimentary breccia, but inasmuch as it is believed to be an alluvial fan deposit the term "fanglomerate" seems more appropriate.

The terms "arkosic" or "feldspathic", as applied to the Triassic rocks of the Deep River basin, refer to any rock that has an appreciable quantity of feldspar (at least several percent, or enough to be readily recognizable in a hand specimen, either with the unaided eye or by use of a hand lens). Many of the sandstones are arkosic, but few of them contain enough feldspar (25 percent) to be properly called arkoses.

Roundness of mineral grains or rock fragments is listed in five categories that are described and illustrated by Pettijohn (1949, p. 51–53). These categories are as follows:

Angular: edges and corners sharp; shows no appreciable wear. Subangular; principal edges and corners slightly smoothed; shows evidence of wear. Subrounded: principal edges and corners smooth curves, minor edges and corners slightly smoothed; shows considerable wear. Rounded: most secondary edges and corners destroyed; flat faces only partly destroyed. Well rounded: all original edges, corners, and flat faces destroyed; surface consists entirely of broad curves.

In the Deep River Triassic sediments, the constituent mineral grains and rock fragments exhibit a wide range of shapes, partly inherited from the parent rock and partly acquired by breakage in transport. Grain shapes are commonly expressed as "sphericity" (the more nearly the shape of a grain approaches a sphere, the higher is the sphericity of the grain). There is little relationship between shape or sphericity and degree of roundness in these sediments. Mineral grains or rock fragments may exhibit very different shapes or sphericities, but they may show the same amount of rounding.

Rock colors are listed in this report in terms used in the Rock-Color chart distributed by the National Research Council (Goddard and others, 1948). The colors are expressed as hue and chroma, and the appropriate letter-number symbol is also shown where a specific color is intended.

STRATIGRAPHY

LITHOLOGIC DIVISIONS

Sedimentary rocks of the Deep River Triassic basin are divided into three units; from oldest to youngest, these are called the Pekin, Cumnock, and Sanford formations. The Pekin and Sanford formations are composed dominantly of red, brown, or purple claystone, siltstone, sandstone, conglomerate, and fanglomerate. The Cumnock formation consists of gray and black claystone, shale, siltstone, fine-grained sandstone, and two beds of coal. Some claystone and shale, and most siltstone and sandstone in this formation are calcareous. Siderite-bearing carbonaceous shale, known as blackband, is commonly present near the coal beds. Black shale and blackband in the Cumnock formation contain small amounts of shale oil, and phosphorous- and nitrogen-bearing compounds.

Although the three Triassic formations are distinguished by differences in color and gross lithology, the contacts between them are gradational and must be located arbitrarily in some places. In general, the top of the Cumnock formation is drawn at the base of the lowest persistent red or brown stratum above the coal beds, and the base of the Cumnock formation is drawn at the top of the highest persistent red or brown stratum below the coal beds. However, beds lithologically similar to strata in the Cumnock formation are present locally in the lower part of the Sanford and in the upper part of the Pekin formations. The maximum combined thickness of the Triassic formations is 7,000 to 8,000 feet in the Sanford basin, 4,000 to 5,000 feet in the Colon cross structure, and about 10,000 feet in the Durham basin.

Each formation changes in texture, in thickness, and in composition, both transversely and longitudinally, within the Deep River basin. In the center of the Sanford and Durham basins the formations are composed dominantly of the finer-grained sediments—claystone, shale, siltstone, and fine-grained sandstone. They grade transversely into coarse-grained or conglomeratic sandstone, conglomerate, and fanglomerate near the southeastern border of the Triassic trough, and they grade longitudinally into coarse sandstone and conglomerate in the Colon cross structure. The Pekin and Sanford formations are thickest along the southeast side of the Deep River basin, where the sediments are mostly coarse-grained; the Cumnock formation and the coal and black shale beds within it are thickest in the northwestern part of the Sanford basin, where the sediments are mostly fine-grained.

In the Colon cross structure the Cumnock formation loses its identity as it grades laterally into red and brown coarse-grained sandstone and conglomerate, which are indistinguishable from beds in the Pekin and Sanford formations. Longitudinal changes in thickness and coarseness of formations in the Deep River basin are illustrated in plate 4. Longitudinal changes in the composition of the formations are also present; these changes correspond roughly to changes in the composition of the pre-Triassic source rocks bordering the basin.

PREVIOUS DESCRIPTION AND CORRELATION

The first attempt to divide the Triassic sedimentary rocks of the Deep River coal field into formations was by Ebenezer Emmons, who suggested a threefold division of these rocks in his report of 1852 (p. 120) as follows:

> The coal seams of Deep River may be described, under three grand divisions, proceeding from the inferior to the superior beds:
> 1. Inferior conglomerates, and sandstones, below the green and black slates.
> 2. Black slates, with their subordinate beds and seams.
> 3. Sandstones, soft and hard, with the freestones, grindstone grits, and superior conglomerates.

Emmons also recognized these three divisions in his report of 1856 (p. 228), stating:

> A natural division seems to exist when we take into account the physical characters of the formation only; and indeed it would be disregarding important features, were these to be passed by unnoticed. According then to these features, the series should be divided into three great deposits, the lower red sandstone and its conglomerate; the coal measures including slates, shales and drab colored sandstones, with their subordinates: and lastly, the upper red sandstones and marls.

On the geologic sketch map accompanying his later report Emmons further divided the coal-bearing formation into an upper member called the "Salines" (defined on pages 232–233 of the report as the salt-bearing "drab and gray sandstone" overlying the coal) and a lower member called the "coal slate and coal." In their report of 1923, Campbell and Kimball (p. 20) rejected this twofold division of the coal-bearing formation as being unmappable, but the three formations recognized by Emmons were accepted, further defined, and named by Campbell and Kimball as follows:

> The Newark group in the Deep River field consists of three generally recognizable parts, by geologists called formations;

a lower formation composed largely of red and brown sandstone, a middle formation of light-colored or drab shale, sandstone and coal beds; and an upper formation of mainly red conglomerate of great, though unknown thickness. In places these formations are clearly marked and easily followed on the surface, but in other places the middle formation disappears, being either faulted out or replaced by red sandstone or conglomerate similar to that in the other formations. As it is desirable to map and describe these formations, it seems best to give them specific names so as to simplify the descriptions and the reference to the formations as much as possible. In accordance with this idea, the name Pekin is selected for the lowest formation, Cumnock for the middle formation, and Sanford for the upper formation.

For purposes of mapping and discussion, the Pekin, Cumnock, and Sanford formations as defined by Campbell and Kimball have been accepted in the present report as the most logical divisions of the sediments in the Deep River basin. The lateral continuity of these formations, particularly within the Colon cross structure, and the correlation of the formations at the south end of the Durham basin with those in the Sanford basin (as described in this report and as shown in pl. 1) do not agree, however, either with the interpretation shown on the geologic map accompanying the report by Campbell and Kimball or with the earlier views held by Emmons. Emmons believed that the strata now included within the Sanford formation were considerably younger than the underlying rocks, that this formation cut obliquely across the underlying (Cumnock and Pekin) formations in the Colon cross structure, and that all the Triassic rocks in the Durham basin belonged to the upper (Sanford) formation. Emmons' concept is shown diagrammatically in figure 5 (top diagram).

Campbell and Kimball thought that all three formations were present in the south end of the Durham basin. They identified strata near Moncure, in the lower part of the Triassic deposits, as part of the Cumnock formation; they thought that the Pekin formation was much thinner and that the Sanford was much thicker there than in the Sanford basin. Campbell and Kimball's concept is shown diagrammatically in figure 5 (middle diagram).

Recent detailed mapping shows that the Pekin, Cumnock, and Sanford formations are all present in the southern part of the Durham basin, and that they have about the same relative position as in the Sanford basin (see fig. 5, bottom diagram). Studies of the facies changes in these sediments indicate, as stated previously, that the absence of the Cumnock formation between the Durham and Sanford basins is a result of gradation of the fine-grained gray and black strata

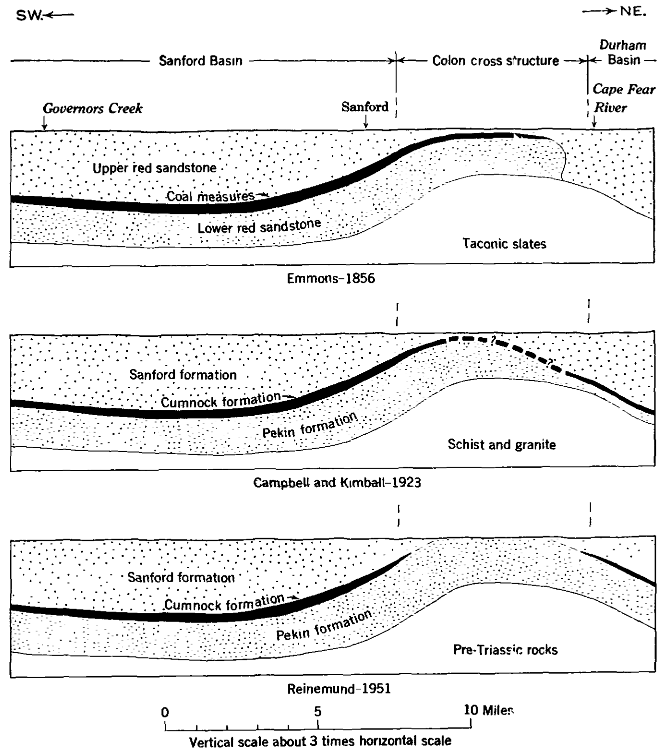


FIGURE 5.—Longitudinal sections showing proposed correlations of formations in Sanford basin, Colon cross structure, and Durham basin.

characteristic of the Cumnock formation into coarse-grained red and brown beds that are indistinguishable from strata in the Pekin and Sanford formations.

PEKIN FORMATION

The Pekin formation, lowest of the three Triassic formations in the Deep River basin, lies unconformably on the pre-Triassic metamorphic and igneous rocks at the bottom of the Triassic sedimentary wedge and crops out in a belt along the northwest side of the basin. The outcrop of this formation, which is shown on the geologic map (pl. 1), ranges in width from three-fifths of a mile to 3½ miles in the Sanford basin, and attains a width of 4½ miles in the Colon cross structure and in the southern part of the Durham basin. This variance in width of outcrop is partly a result of faulting and partly a result of changes in thickness of the formation. The Pekin crops out over a little less than a fourth of the Sanford basin, a little more than half of the Colon cross structure, and a little more than a fourth of the entire southern half of the Deep River Triassic basin.

In general, the Pekin formation is poorly exposed in the Deep River basin, and present knowledge of its lithologic character is based on examination of many small, scattered outcrops rather than on a detailed study of one or more type sections. Campbell and Kimball (1923, p. 21) found much better exposures of the formation in the Wadesboro Triassic basin near the town of Pekin in Montgomery County, and for this reason they named it the Pekin formation.

In the northern part of the Sanford basin, the Pekin formation is 1,750 to 1,800 feet thick. The lower 80 to 100 feet consists of gray or brown conglomerate, or of conglomeratic sandstone. A distinctive yellowish-gray (5Y8/1) or grayish-orange (10YR7/4) medium- or coarse-grained, crossbedded arkosic sandstone, which averages about 30 feet in thickness, is present near the center of the formation, from north of Cumnock to west of Haw Branch. Near the bottom, this bed is in part conglomeratic and in part shaly; the bed grades upward into red, brown, or purple, fine- and medium-grained, crossbedded sandstone. The rest of the formation consists mainly of lenticular beds of red, brown, or purple claystone, siltstone, and fine-grained sandstone; however, interbedded yellowish-gray (5Y8/1), light-gray (N7), or light greenish-gray (5GY8/1) siltstone and fine-grained sandstone are also present in the top 100 feet.

The lithologic character of the Pekin formation in the northern part of the Sanford basin, northwest of the Deep River fault shown on the geologic map (pl. 1), is illustrated in figure 6. In this part of the field the formation consists of approximately 2 percent conglomerate, 15 percent sandstone, 29 percent siltstone, and 54 percent claystone or shale.

About 3,000 to 4,000 feet of strata belonging to the Pekin formation are exposed in the western part of the Sanford basin. The basal conglomerate and associated gray or brown conglomeratic, arkosic sandstone constitute the lower 300 feet of the formation. The rest of the formation consists mainly of lenticular beds of red, brown, or purple claystone, siltstone, fine- or medium-grained sandstone, and subordinate amounts of brown or gray, medium- to coarse-grained, crossbedded arkosic sandstone which is locally conglomeratic. The best exposure of a gray, arkosic sandstone in this part of the field is in a cut on State Highway 27, about 2 miles west of Carthage. A sketch of this exposure is shown in figure 7–A. This bed of arkosic sandstone, not more than 1,000 feet below the top of the formation, was traced laterally for more than a mile.

Laminated, salt-bearing, ripple-marked shale of probable lacustrine origin, about 1,000 feet above the base of the formation, is exposed 4½ miles west of Carthage. An exposure, shown in figure 7–B, of beds near the top of the formation along State Highway 27 shows the interfingering and lateral gradation of lithologic units that is characteristic of this formation. The typical lithologic character of the interbedded red, brown, or purple strata, which make up at least three-fourths of the Pekin formation in this part of the field, is shown by the following section of beds in the middle of the formation exposed along McLendons Creek.

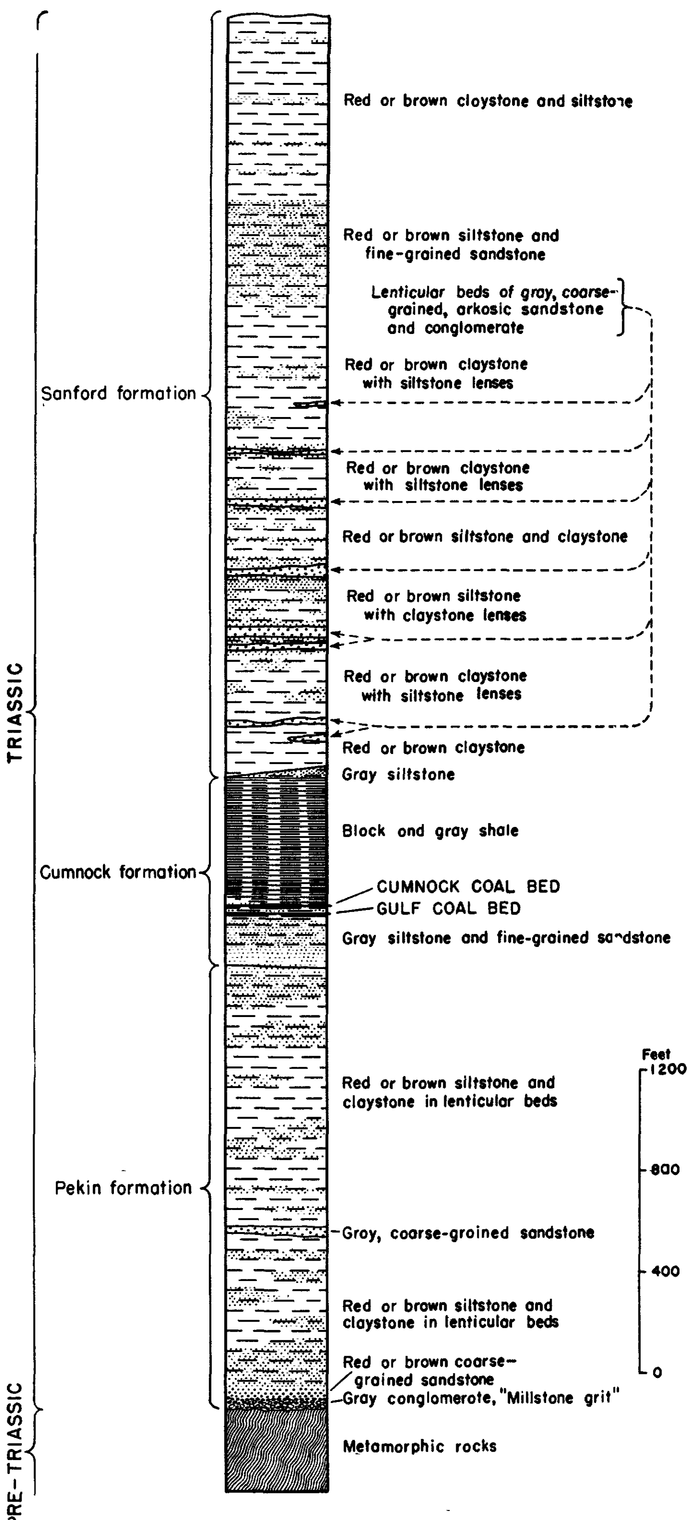
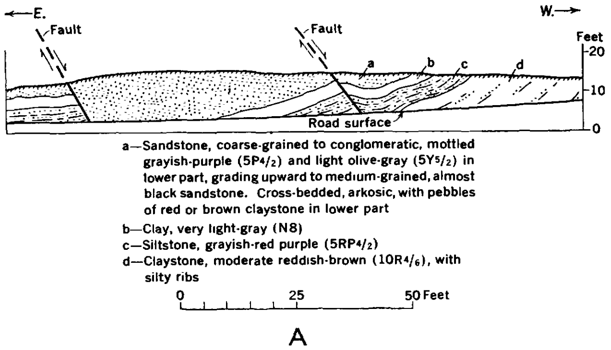


FIGURE 6.—Generalized stratigraphic section of beds exposed north of the Deep River fault.



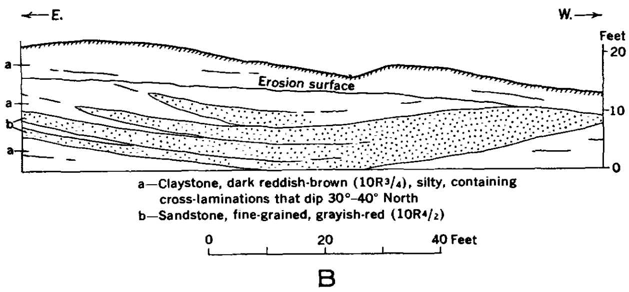


FIGURE 7.—*A*, Sketch showing outcrop of arkosic sandstone in Pekin formation, 2 miles west of Carthage. *B*, Sketch showing interfingering of sandstone and claystone in Pekin formation, 1½ miles west of Carthage.

Section of beds in middle of Pekin formation exposed on east bank of McLendons Creek, 4 miles west of Carthage

	Feet
Claystone, moderate reddish-brown (10 R 4/6), massive, structureless	15
Sandstone, medium-grained, yellowish-gray (5 Y 7/2) at bottom, grading upward to fine-grained, dark reddish-brown (10 R 3/4)	8
Claystone, silty, grayish-red (10 R 4/2), massive, structureless	24
Siltstone, grayish-red (10 R 4/2) in 3- to 6-inch beds	3
Claystone, silty, grayish-red (10 R 4/2), massive, structureless	18
Sandstone, fine-grained, dark reddish-brown (10 R 3/4) in 2- to 6-inch beds	10
Claystone, moderate reddish-brown (10 R 4/6), massive, structureless	10
Sandstone, fine-grained, dark reddish-brown (10 R 3/4)	1
Claystone, moderate reddish-brown (10 R 4/6), massive, structureless	10
Siltstone, grayish-brown (5 YR 3/2)	1
Claystone, silty, grayish-red (10 R 4/2), massive, structureless	15
Erosion surface.	
Siltstone, dark reddish-brown (10 R 3/4), in 2- to 5-inch beds	3
Claystone, moderate reddish-brown (10 R 4/6), massive, fractured	15
Siltstone, grayish-brown (5 YR 3/2), massive, structureless	5+

In the western part of the Sanford basin, it is estimated that the Pekin formation consists of approximately 4 percent conglomerate, 20 percent sandstone, 40 percent siltstone, and 36 percent claystone and shale. Here, the formation contains more sandstone and conglomerate than it does in the northern part of the Sanford basin, and it is about twice as thick.

About 3,500 feet of strata belonging to the Pekin formation are exposed in the Colon cross structure northeast of Sanford. North of Colon, the basal conglomerate is locally less than 50 feet thick (see pl. 1); farther northeast, on Copper Mine Creek southeast of the Deep River School, the bottom 500 feet of the formation is almost entirely conglomerate. The rest of the formation in this part of the field consists mainly of gray, purple, red, or brown conglomerate and sandstone with interbedded red, brown, or purple claystone, siltstone, and fine-grained sandstone. In the Colon cross structure, it is estimated that the Pekin formation consists of about 24 percent conglomerate, 35 percent sandstone, 28 percent siltstone, and 13 percent claystone; there it is considerably coarser than it is in the Sanford basin.

A belt of light olive-gray and brownish-gray rocks, consisting mainly of conglomerate and sandstone, and containing a few thin beds of shale, is present in the Pekin formation southeast of the Deep River School. This belt crops out along Copper Mine Creek for about a third of a mile upstream from the coal pit north of Zion Church (shown on pl. 1). The shale and some of the sandstone in this belt resemble some of the strata in the Cumnock formation in the Sanford basin, and Campbell and Kimball (1923, p. 42) reported that a 3-inch coal bed was exposed in the coal pit (now caved and flooded). This led these authors to designate the belt of light-gray rock as the Cumnock formation—a correlation which resulted in an exceptionally thin Pekin formation and an unusually thick Sanford formation in this area, as shown in figure 5.

Detailed study of this belt shows that these rocks grade both toward the northeast and toward the southwest into red, brown, and gray strata, which are typical of the Pekin formation and which underlie the Cumnock formation in both the Sanford basin and the Durham basin. Although some shale and sandstone in this belt resemble strata in the Cumnock formation, these rocks also resemble strata in the previously described gray sandstone bed in the middle of the Pekin formation in the northern part of the Sanford basin. Furthermore, this belt does not contain the gray or black fissile shale that is characteristic of the Cumnock formation in the Durham and Sanford basins. For these reasons, this belt is regarded as only a local facies of the Pekin formation that should not be correlated with the Cumnock.

In the southern part of the Durham basin the Pekin formation is approximately 3,000 feet thick. The bottom 300 feet of the formation consists of gray or red conglomerate. This is overlain by 200 to 300 feet of grayish-pink, fine- to coarse-grained arkosic sandstone, mostly in beds 1 to 6 inches thick. The rest of the formation consists mainly of red or brown claystone, siltstone, or fine-grained sandstone and small amounts of gray or purple, medium- to coarse-grained arkosic sandstone. The formation, as a whole, is considerably finer-grained in this area than it is in the Colon cross structure farther west, but the exposures are insufficient to provide an accurate estimate of the relative proportions of coarse and fine sediments.

The distribution of conglomerate, sandstone, and shale in the Pekin formation within the Deep River coal field is shown on the lithologic map (pl. 4). This map, based on detailed studies of outcrops, gives only a very generalized picture of the lithology; its purpose is to show the broad changes in the texture of the formations rather than the precise position of a particular bed. In preparing this map, the effects of many cross faults were ignored.

The estimated distribution of conglomerate, sandstone, siltstone, and claystone or shale, the total thickness of the formation and the percentage of red or brown strata in the formation in different parts of the Deep River basin are listed in table 5 to facilitate comparison of lithologic changes in the Pekin formation. These figures are based entirely on data collected from outcrops on the northwest side of the basin. The lithology of the Pekin formation on the southeast side of the basin, where it is deeply buried, is not known. Evidence (to be presented later) suggests that most of this formation was deposited by streams flowing from the southeast; therefore, it is probable that the Pekin formation becomes thicker and coarser-grained toward the southeast.

CUMNOCK FORMATION

The Cumnock formation lies conformably on the Pekin, crops out in a narrow belt along the center and northwestern side of the Sanford basin, is duplicated four times by longitudinal faulting in the western part of this basin, and is present locally at the southern end of the Durham basin. In the Colon cross structure, the Cumnock formation grades laterally into conglomerate and sandstone beds that are indistinguishable from strata in the Pekin and Sanford formations. Less than a tenth of the southern part of the Deep River Triassic basin, covered by the geologic map (pl. 1), is occupied by the Cumnock outcrop.

Campbell and Kimball (1923, p. 25–43) described the Cumnock formation in considerable detail, and they named it for the Cumnock mine, where sections of the formation were exposed in the main shaft and were penetrated in four holes drilled nearby (holes DH–1, 2, 3, and 4, shown on pl. 1). The shaft was put down in the years 1852 to 1854, exposing 460 feet of strata in the upper part of the Cumnock formation, which were described by Wilkes (1858, p. 6). The holes were drilled during World War I; holes DH–1, 2, and 3 penetrated the lower part of the Sanford formation and all of the Cumnock formation above the coal beds (506 to 561 feet); therefore, they provide an even better section than that exposed in the mine shaft. These five sections of the Cumnock formation at the type locality are shown in figure 8, which is adapted from figure 5 of the Campbell and Kimball report. The record of hole DH–1 is given in the Appendix at the end of this report.

In recent years more information about the Cumnock formation has been obtained from many other holes drilled to test the coal in the Deep River field. Measured sections of beds penetrated in most of these holes are also given in the Appendix. As a result of this extensive drilling, the lithology of the Cumnock formation is known in much more detail now than at the time Campbell and Kimball prepared their report.

In the north-central part of the Sanford basin, northwest of the Deep River fault, the Cumnock formation is from 750 to 800 feet thick. The general lithology of the formation in that part of the field is shown in figure 6. Two beds of coal, one called the Cumnock coal bed and the other called the Gulf coal bed, are from 200 to 260 feet above the base of the formation. The strata below these beds consist mainly of light-gray (N7), medium dark-gray (N4), and dark greenish-gray (5G4/1) siltstone and fine-grained sandstone and contain small amounts of claystone and shale. These rocks generally weather to light olive-gray (5Y6/1), light brownish-gray (5YR6/1), or moderate yellowish-brown (10YR5/4) that is distinctively different from the rocks in the Pekin formation. The strata above these beds consist mainly of medium light-gray (N2) to black shale, and include small amounts of claystone, siltstone, and sandstone. The shale is irregularly calcareous and carbonaceous.

In drilling for coal in this part of the field, it has been observed that the highest black shale is usually 480 to 500 feet stratigraphically above the coal. This is the only lithologic marker that is consistent enough to be of use in determining distance to coal. Beds of light-gray to medium dark-gray siltstone and fine-

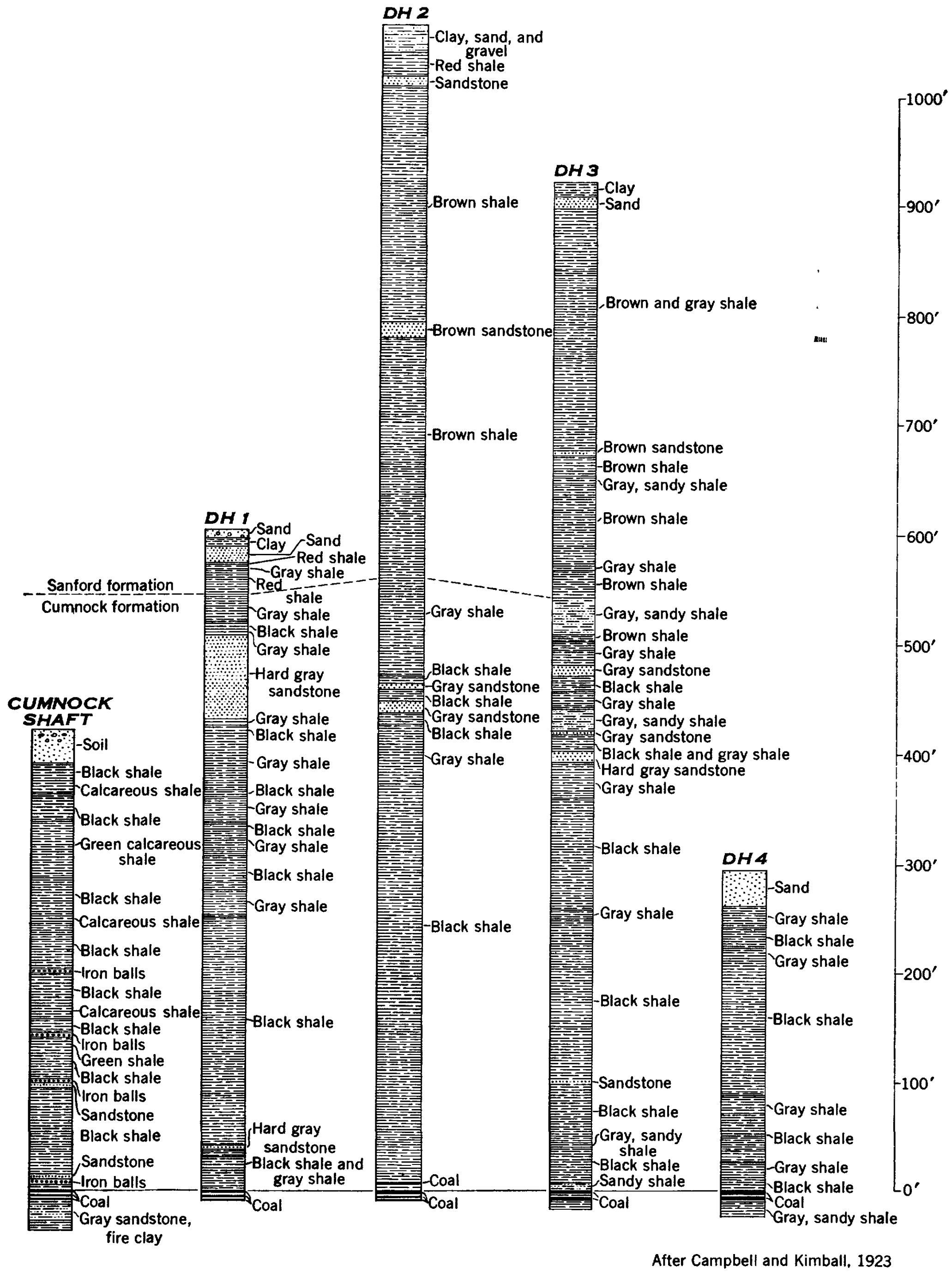


FIGURE 8.—Sections of the Cumnock formation in the Cumnock shaft and in drill holes near the Cumnock mine.

grained sandstone, as much as 50 feet thick, are present above the highest black shale in the Cumnock formation; these beds are also present below the lowest red, or brown, beds in the Sanford formation.

Detailed descriptions of the upper part of the Cumnock formation northwest of the Deep River fault have been obtained by study of cores from test holes, but the only complete detailed section of this formation above the coal beds, in an area not affected by important faults or igneous intrusions, was recorded by the Bureau of Mines in drill hole BMDH DR–1. In this hole, the main bench of the Cumnock coal bed is 508 feet below the lowest red or brown bed in the Sanford formation and is 486 feet below the highest black shale in the Cumnock formation. The 508 feet of strata above the Cumnock coal bed consist of 2 percent sandstone, 12 percent siltstone, 15 percent claystone, and 71 percent shale. Almost half of the rocks are calcareous, but no limestone is present. Practically all the sandstone, siltstone, and claystone is gray, whereas only about a fourth of the shale is gray and the rest is black. Most of the black shale contains a dwarf fauna of fish and brachiopods, the fossil content is highest in beds with the best-developed fissility. Plant fragments are abundantly distributed in the gray shale, claystone, and siltstone.

The following summary of lithologic characteristics of rocks encountered in hole BMDH DR-1 is typical of the upper part of the Cumnock formation over most of the area northwest of the Deep River fault.

Proportions of sandstone, siltstone, claystone, and shale, of black and gray strata, and of calcareous strata in upper part of Cumnock formation in drill hole BMDH DR-1

	Content		Black strata		Gray strata		Calcareous strata	
	Feet	Percent	Feet	Percent	Feet	Percent	Feet	Percent
Sandstone	11	2	--------	--------	11	100	--------	--------
Siltstone	60	12	1	2	59	98	41	68
Claystone	76	15	--------	--------	76	100	29	38
Shale	361	71	281	78	80	22	186	52
Total	508	100	282	55	226	45	256	48

Coal beds in the Cumnock formation are thickest northwest of the Deep River fault between the Carolina mine and the Black Diamond mine (see pl. 1). The Cumnock coal bed consists of a main bench (3 to 4 feet thick over most of this area), overlain by a top bench (locally, as much as 2½ feet thick), which is consistently present only southwest of Gulf, and underlain by one or more lower benches (a few inches to more than 3 feet thick). Several inches of shale or siltstone generally separate the top bench from the main bench, and 18 inches or more of brownish-black (5YR2/1) or olive-black (5Y2/1) ferruginous shale, known as blackband, usually separate the lower benches from the main bench.

The Gulf coal bed, which lies from 25 to 45 feet below the main bench of the Cumnock bed, has been found only between the Black Diamond mine and the Carolina mine. Over most of this area it consists of a single coal bed (a few inches to almost 3 feet thick) but a lower bench (a few inches thick) is also present in some places. Blackband beds are commonly associated with the Gulf coal bed. These coal and blackband beds are described in more detail in the section on economic geology. The general distribution of these beds and the lithologic character of adjacent strata from the Carolina mine to the Black Diamond mine are shown in figure 9.

A delta-shaped wedge of sandstone overlies the main bench of the Cumnock coal bed between Gulf and Cumnock; it is thickest (37 feet) in drill hole BMDH E-1 near the coal outcrop, and it thins rapidly in all directions. This deposit is at the stratigraphic position occupied by the "top bench" farther west. A thinner sandstone lens overlies the coal southeast of Cumnock.

It was recognized by Emmons (1856, p. 234) and later by Campbell and Kimball (1923) that the Cumnock formation and associated gray and black fissile shales are thickest in the vicinity of Cumnock and Gulf, and that the coal beds are thickest and least shaly in the same area. Recent mining, drilling, and detailed mapping support this concept and show that the fine-grained sediments and coal beds grade laterally into coarser-grained sediments toward both the southeast and the southwest. This textural change is accompanied by a lateral gradation of beds near the top and bottom of the formation into red and brown strata typical of the underlying Pekin and overlying Sanford formations.

Thinning and coarsening of the Cumnock formation are particularly rapid southeast of Cumnock—as shown on the lithologic map (pl. 4). The coal beds, which have an aggregate thickness of nearly 8 feet at Cumnock, have a total combined thickness of not more than 2 or 3 feet in the vicinity of the McIvor mine, 2 miles southeast of Cumnock (see pl. 1), and they disappear before the Cumnock formation crosses the Seaboard Railroad, 2 miles north of Sanford. Shale, which constitutes about two-thirds of the formation near Cumnock, probably forms less than a third of the formation near the McIvor mine, and 4 miles farther southeast, the formation consists entirely of siltstone and sandstone.

Southeast of the McIvor mine, gradation of beds in the Cumnock formation into red and brown siltstone, sandstone, and conglomerate, which cannot be distinguished from strata in the Pekin and Sanford formations, has resulted in progressive thinning of the Cumnock formation as a lithologically distinct stratigraphic unit until it finally loses its identity about 1½ miles east of Sanford. On the headwaters of Wallace Branch, about a mile east of Sanford, the formation is less than 200 feet thick; two-thirds of it is gray sandstone and shaly siltstone, and the rest is gray conglomerate.

Thinning and coarsening of the Cumnock formation are considerably less abrupt southwest of the Cumnock-Gulf area. From Gulf to Haw Branch the southwestward thinning and increase in shale content of the coal beds (described in the chapter on coal) are accompanied by a gradual decrease in the over-all shale content of the formation. South of Carbonton, the Cumnock outcrop is offset and duplicated by the Deep River fault, and in

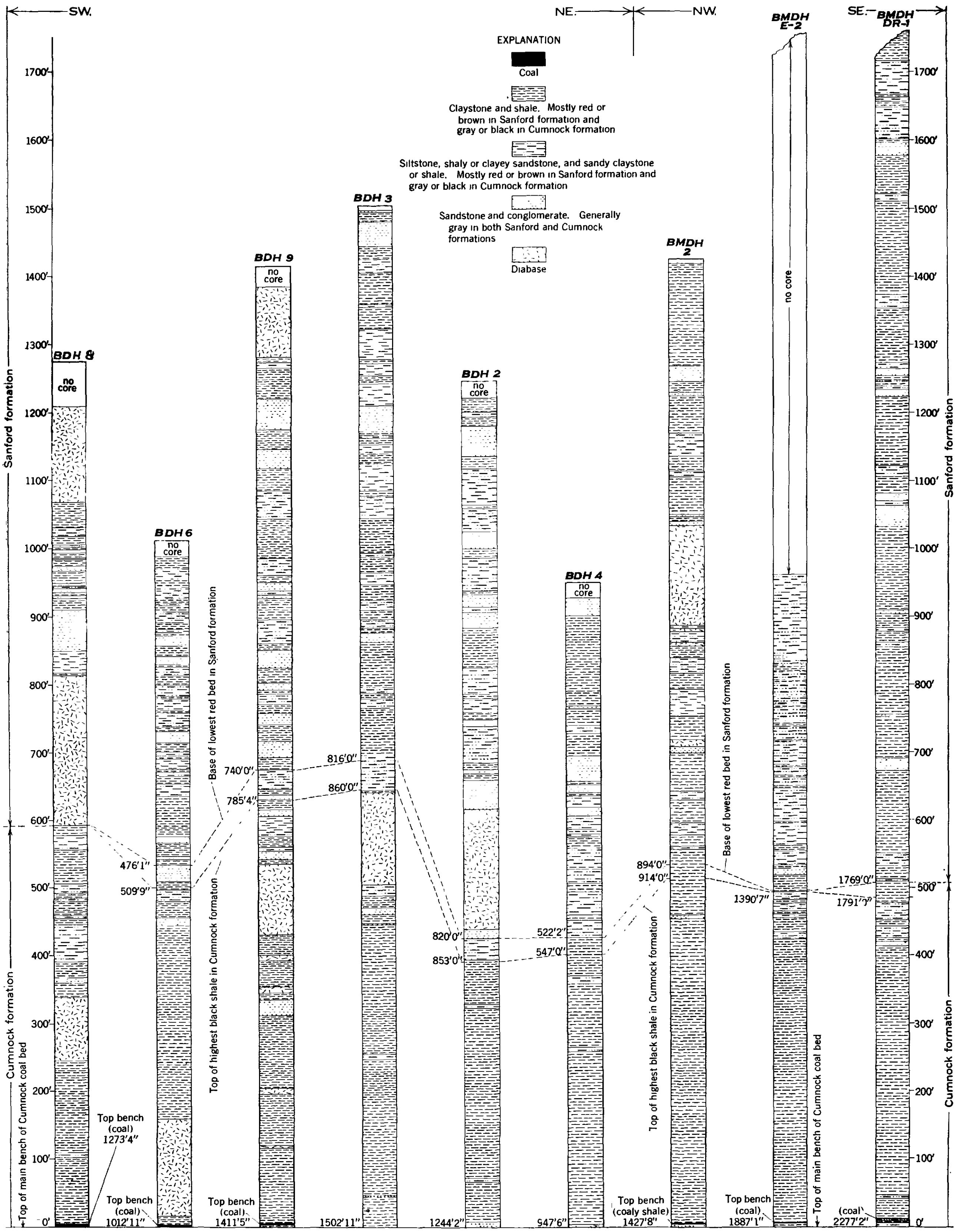


FIGURE 9.—Sections of the Cumnock and Sanford formations in drill holes north of the Deep River fault.

eastern Moore County it is duplicated three more times by longitudinal faults, which are similar to the Deep River fault. This repetition provides ample opportunity to study the lithology of the formation in this area. Despite an intensive search of these outcrops of the Cumnock formation, coal has not been observed southwest of the Gardner mine (where the coal beds have a combined thickness of 3 to 4 feet).

Carbonaceous shale has been observed 1½ miles west of Horse Shoe Bridge, which crosses Deep River (as shown on pl. 1), and at a prospect pit 2 miles south of this bridge. Gray and black fissile shale in the Cumnock formation crops out from 1 to 3 miles west of Horse Shoe Bridge and at scattered localities as far as 3 miles south of the bridge. Toward the southwest, however, the proportion of shale and claystone in this formation steadily diminishes, and the total thickness of the formation steadily decreases.

No fissile shale has been observed in the outcrops of the Cumnock formation from 2 to 4 miles north of Carthage, and none has been observed in this formation west of Carthage. Where the Cumnock formation is exposed along Killetts Creek, 2 miles west of Carthage, it is about 520 feet thick and consists almost entirely of siltstone and sandstone. A section of the formation in this area is described below. The beds are listed in their proper stratigraphic order (from top to bottom).

	Approximate thickness (feet)
Sanford formation:	
Sandstone, grayish-red (10R4/2) and pale brown (5YR5/2), fine-grained	25
Cumnock formation:	
Sandstone, light olive-gray (5Y6/1), fine-grained, arkosic, in beds a few feet thick	60
Siltstone, light olive-gray (5Y6/1), in beds a few inches thick	46
Sandstone, brownish-gray (5YR4/1), fine-grained, cross-bedded, partly quartzitic, in beds a few inches to several feet thick	81
Siltstone, light olive-gray (5Y6/1), in beds a few inches thick, in part shaly	116
Sandstone, light olive-gray (5Y6/1) to dark yellowish-orange (10YR6/6), medium-grained, arkosic, grading upward to brownish-gray (5YR4/1), fine-grained sandstone in beds several feet thick	103
Sandstone, light olive-gray (5Y6/1), fine-grained, quartzitic, in beds a few inches to several feet thick	78
Sandstone, dusky-yellow (5Y6/4), fine-grained, in beds a few inches thick	27
Pekin formation: Siltstone, grayish-red (10R4/2)	25

A 2-mile gap exists in the outcrop of the Cumnock formation northwest of Carthage (shown on pl. 1). This disappearance of the formation may be a result of lateral gradation of the gray Cumnock strata into red and brown beds like those in the Pekin and Sanford formations, but evidence suggests that faulting is the cause. Both on the north side and on the south side of this gap, the Cumnock formation is more than 500 feet thick, contains very little interbedded red or brown strata, and shows no evidence of abrupt lateral gradation. On the other hand, there is evidence of important faulting in this part of the field, and such faulting could account for the local disappearance of the Cumnock outcrop in a manner described in the chapter on structure.

Rocks typical of the Cumnock formation, and tentatively correlated with the Cumnock, crop out about a mile north of Brickhaven in the southern part of the Durham basin at about the same stratigraphic position as that occupied by the Cumnock in the Sanford basin. Near the road from Brickhaven to Moncure, several prospect pits have been opened on a 5-inch bed of shaly coal that overlies 5 inches of carbonaceous shale. Beds of gray fissile and thin-bedded shale, thin-bedded siltstone, and sandstone lie below and above this coal and carbonaceous shale. The entire formation at this locality is not more than a few hundred feet thick and is mostly concealed by river terrace deposits, alluvium, and a heavy forest cover. Similar rocks crop out along the edge of a river terrace at the Carolina Power and Light Company plant on the east side of the Cape Fear River. West of the Cape Fear River this belt of rocks is concealed beneath terrace deposits and alluvium, but it probably grades westward into coarser strata of the Pekin and Sanford formations.

No attempt has been made to trace the Cumnock formation northeast of the mapped area, but it probably extends continuously for only a short distance. Coal-bearing rocks in eastern Chatham County, about 6 miles northeast of Merry Oaks, are at about the same stratigraphic position as the Cumnock formation.

At the southern end of the Durham basin, and in the southwestern part of the Sanford basin, the outcrops of the Cumnock formation shown on the geologic map (pl. 1) differ considerably from the Cumnock outcrops shown on the map accompanying the Campbell and Kimball report. In both these areas, strata identified by Campbell and Kimball as belonging to the Cumnock formation are now believed to be near the bottom of the Pekin formation. These authors apparently failed to observe the poorly-exposed but stratigraphically-higher rocks that are more typical of the Cumnock formation and are at approximately the correct stratigraphic position.

SANFORD FORMATION

The Sanford formation includes the youngest Triassic rocks in the Deep River basin. It lies conformably on the Cumnock formation in the Sanford and Durham basins, but it appears to lie unconformably on the Pekin formation in the Colon cross structure. It borders the southeast edge of the Deep River basin throughout the mapped area in a belt that attains a breadth of 10½ miles in the eastern part of the Sanford basin, narrows to little more than half a mile in the Colon cross structure, and broadens again to a width of 3 or 4 miles in the southern part of the Durham basin. The Sanford formation underlies approximately two-thirds of the Sanford basin, almost half of the Colon cross structure, and almost two-thirds of the entire southern half of the Deep River Triassic basin.

Although it is well exposed throughout most of its broad belt of outcrop, the Sanford formation contains few distinctive beds and no subdivisions that are consistently mappable. The strata within the formation are lenticular or laterally gradational; no outcrop gives a section that is typical outside of a small area. In the absence of a type section, Campbell and Kimball named the formation for the city of Sanford, which lies in the belt occupied by this formation.

About 3,000 feet of strata belonging to the Sanford formation are present in the north-central part of the Sanford basin, northwest of the Deep River fault. These strata consist of red or brown claystone, siltstone, and fine-grained sandstone, and interbedded lenticular, gray, coarse-grained or conglomeratic, arkosic sandstone in the lower 1,400 to 1,600 feet of the formation. The general lithology of the Sanford formation in this part of the field is shown in figure 6. Numerous holes drilled to test for coal northwest of the Deep River fault have penetrated the lower 600 to 800 feet of the Sanford formation. The logs of these holes show that 10 to 30 percent of the strata in this interval are sandstone, 25 to 45 percent are siltstone, and 25 to 55 percent are claystone. From 50 to 70 percent of the rocks in the lower 600 to 800 feet are red or brown; the rest are gray. The record of drill hole BMDH DR–1 (see Appendix) gives a detailed description of the lower 1,743 feet of strata in the Sanford formation. Lithology of rocks encountered in this hole is summarized below.

Proportions of sandstone, siltstone, and claystone, and of dark-colored and light-colored strata in lower part of Sanford formation in drill hole BMDH DR–1

	Content		Dark strata (red or brown)		Light strata (gray)	
	Feet	Percent	Feet	Percent	Feet	Percent
Sandstone	133	8	27	20	106	80
Siltstone	294	17	287	98	7	2
Claystone	1,316	75	1,253	95	63	5
Total	1,743	100	1,567	90	176	10

All of the Sanford formation is exposed in the northeastern part of the Sanford basin, southeast of the Deep River fault. The total thickness of the formation in this area is about 4,000 feet. The strata in the lower and middle parts of the formation are coarser grained than the strata northeast of the Deep River fault; most strata become progressively coarser toward the southeast and grade laterally into conglomerate or fanglomerate near the southeast Triassic border. The upper 1,000 feet of the formation consists mainly of red, brown, or purple coarse-grained, arkosic sandstone and conglomerate, and subordinate amounts of claystone, siltstone, and fine-grained sandstone. Fanglomerate is present along the entire southeast edge of the basin, except for a short distance south of Sanford. More than 90 percent of the strata in the formation in this part of the field are red or brown; the beds of gray arkosic sandstone northwest of the Deep River fault grade southeastward into red or brown sandstone and conglomerate.

From 3,500 to 4,000 feet of strata belonging to the Sanford formation are present in the southwestern part of the Sanford basin. The formation is, in general, well exposed in this part of the basin except for the top several hundred feet of strata, which are partly covered by post-Triassic sand and gravel deposits. The lower part of the formation does not contain as much gray, coarse-grained arkosic sandstone as it does farther northeast; the middle of the formation contains more arkosic sandstone, and the upper part contains less. Fanglomerate is present along the southeastern border of the basin. Exposed strata in the Sanford formation in Moore County consist of approximately 18 percent conglomerate or fanglomerate, 20 percent sandstone, 26 percent siltstone, and 36 percent claystone or shale. About 82 percent of the rocks are red or brown. The following sections are typical of strata at the bottom and in the middle of the Sanford formation in the southwestern part of the Sanford basin.

Section of beds at base of Sanford formation at Horse Shoe Bridge

	Feet
Sandstone, fine-grained to coarse-grained, light gray (N7) to yellowish-gray (5Y7/2), arkosic	8
Claystone, moderate reddish-brown (10R4/6)	3
Claystone, light olive-gray (5Y6/1), shaly	4
Claystone, moderate reddish-brown (10R4/6)	4
Fault	
Claystone, light olive-gray (5Y6/1), shaly	8
Fault	
Claystone, moderate reddish-brown (10R4/6)	10
Claystone and siltstone interbedded, yellowish-gray (5Y8/1)	8
Claystone, light olive-gray (5Y6/1), shaly	10
Claystone, moderate reddish-brown (10R4/6), containing silty layers	12

Section of beds at base of Sanford formation at Horse Shoe Bridge—Continued

	Feet
Claystone, light olive-gray (5Y6/1), shaly	3
Claystone, moderate reddish-brown (10R4/6), containing silty layers	4
Claystone, light olive-gray (5Y6/1), shaly	20
Claystone, mottled moderate reddish-brown (10R4/6) and dark reddish-brown (10R3/4)	12
Claystone, light olive-gray (5Y6/1), shaly	3
Claystone, moderate reddish-brown (10R4/6)	4
Base of Sanford formation	

Section of beds near middle of Sanford formation on State Highway 27 at west edge of Carthage

Claystone, moderate reddish-brown (10R4/6)	15+
Siltstone, dark reddish-brown (10R3/4)	3
Sandstone, fine-grained to medium-grained, containing pebbly stringers, dark reddish-brown (10R3/4) containing very dusky red (10R2/2) patches, arkosic, crossbedded	9
Sandstone, conglomeratic, dark reddish-brown (10R3/4), arkosic. Pebbles mostly schist fragments as much as 7 cm across, mostly well-rounded	6
Sandstone, fine-grained to medium-grained, pale reddish-brown (10R5/4) to dark reddish-brown (10R3/4), arkosic	7
Claystone, moderate reddish-brown (10R4/6), silty	9
Sandstone, fine-grained, grayish-red (10R4/2), arkosic	4
Sandstone, medium-grained to coarse-grained, pale reddish-brown (10R5/4), arkosic, crossbedded. Contains lenses and pebbles of moderate reddish-brown clay	8
Claystone, moderate reddish-brown (10R4/6)	10+

In the center of the Colon cross structure, near the Sanford water works, the Sanford formation is not more than 500 to 600 feet thick and consists entirely of fanglomerate. Here, the fanglomerate is composed of unsorted angular to sub-rounded fragments of metamorphic rocks (mainly schist) and quartz in a purple or brown conglomeratic sandstone matrix. This deposit exhibits almost no bedding, but the fanglomerate mass, as a whole, parallels the Triassic border and truncates the underlying, relatively well-bedded strata of the Pekin formation.

In the eastern part of the Colon cross structure, the Sanford formation becomes rapidly thicker—it reaches a thickness of about 6,000 feet on the west side of the Cape Fear River. In this area, the upper part of the formation is composed almost entirely of fanglomerate, whereas the lower part consists of red or brown siltstone and sandstone, separated by sinuous masses of fanglomerate. The fanglomerate shown on the geologic map (pl. 1) includes scattered lenses of fragment-free sandstone and local well-defined beds of conglomerate, but in general, it consists of a jumbled, structureless accumulation of rock fragments ranging from less than an inch to more than 12 inches across. The siltstone and sandstone masses in the lower part of the formation are relatively well-bedded, but the beds are lenticular. Because of the absence of the Cumnock formation, the base of the Sanford has been drawn arbitrarily at the base of a fanglomeratic bed that appears to mark the upper limit of well-bedded strata.

A thickness of 2,000 to 3,000 feet of strata belonging to the Sanford formation is present at the southern end of the Durham basin. The lower two-thirds of the formation is composed mainly of red or brown claystone, siltstone, and sandstone, but is not well exposed within the mapped area. The upper third of the formation consists almost entirely of fanglomerate, although beds of sandstone and conglomerate are present locally in the fanglomerate deposit shown on plate 1 (particularly in the area west of Corinth). Granite debris, probably derived from the Carboniferous (?) granite along the southeastern border of the basin, is an important constituent of the fanglomerate east of the Cape Fear River.

The fanglomerate in the southern part of the Durham basin is not well exposed. In 1949, however, the road from Corinth to Brickhaven was relocated, and a mile west of Corinth the soil over a fanglomerate deposit was scraped off for a distance of about 100 feet. The resulting fresh, nearly horizontal exposure of the southeastward-dipping fanglomerate is described below to illustrate the typical lithologic character of this deposit. Because of the flatness of this exposure and the relative absence of stratification in this deposit, the horizontal distance occupied by each lithologic unit as measured on the surface of the ground—rather than the thickness of the beds—is shown in the following table. In the description of this exposure, note the presence of granite debris, the angularity of the blocks, and the ratios of matrix to blocks.

Section of Rocks in Upper Part of Sanford Formation on Road From Corinth to Brickhaven, 1 Mile West of Corinth.

	Feet [1]
East end of cut.	
Siltstone, dark reddish-brown (10R3/4), containing scattered pebbles of schist and quartz as much as 3 cm across	5+
Fault (vertical)	
Fanglomerate. Red or brown sandstone matrix not more than 20 percent of rock. Jumbled angular or subangular blocks mainly schist and granite, few quartz, mostly 1 cm to 25 cm across. Largest blocks are granite	18
Fault (vertical)	
Sandstone, conglomeratic, dark reddish-brown (10R3/4). Matrix about 70 percent of rock. Pebbles as much as 10 cm across, subangular or subrounded, schist and quartz, having polished surfaces	1

[1] Thickness of each unit, as measured horizontally on surface of ground.

Section of Rocks in Upper Part of Sanford Formation on Road From Corinth to Brickhaven, 1 Mile West of Corinth—Con.

	Feet
Erosion surface (N–S, 30° E.)	
Fanglomerate. Red or brown sandstone matrix about 40 percent of rock. Jumbled angular or subangular blocks mainly schist and granite, few quartz, mostly 1 cm to 20 cm across	6
Erosion surface (N–S, 65° W.)	
Sandstone, medium-grained, dark reddish-brown (10R3/4), containing a few scattered schist and quartz pebbles less than 3 cm across	1
Bedding surface (N. 20° E., 45° SE.)	
Fanglomerate. Red or brown sandstone matrix not more than 20 percent of rock. Jumbled angular or subangular blocks mainly schist and granite, few quartz, mostly 1 cm to 25 cm across	7
Gradational contact	
Sandstone, conglomeratic, moderate reddish-brown (10R4/6). Pebbles, mostly schist, less than 3 cm across, angular or subangular, polished	2
Bedding surface (N. 18° E., 30° SE.)	
Claystone, mottled gray and brown	2
Bedding surface (N. 18° E., 30° SE.)	
Fanglomerate. Red or brown sandstone matrix about 30 percent of rock. Jumbled angular to subrounded schist and granite blocks as much as 20 cm across	15
Gradational contact	
Sandstone, fine-grained to medium-grained, moderate reddish-brown (10R4/6), with lenses of gray or brown conglomeratic sandstone	25
Bedding surface (N–S., 35° E.)	
Sandstone, fine-grained, moderate reddish-brown (10R4/6) containing scattered subrounded schist and quartz pebbles less than 3 cm across	10
Gradational contact	
Fanglomerate. Red or brown sandstone matrix. Angular or subangular fragments of schist as much as 20 cm across	5+
West end of cut.	

GROSS LITHOLOGY AND THICKNESS

The approximate distribution of conglomerate and fanglomerate, sandstone, siltstone, claystone, and shale in the three Triassic formations in different parts of the Deep River basin are listed in table 5. These data show that the Triassic sediments in all the formations are considerably coarser, on the average, in the Colon cross structure than they are in the Sanford basin. They are also coarser in the Colon cross structure than they are in the Durham basin, although the exposures in the Durham basin are not adequate to justify specific estimates in this table. This longitudinal change in texture, which is illustrated on the lithologic map (pl. 4), suggests that the Colon cross structure may have been the site of an alluvial fan during much of the Newark epoch, and that it received coarse sediments at the same time that finer sediments were deposited in the basins on either side of it.

In Cumnock time, coarse red and brown sediments were deposited in this topographically-high fan, while coal and gray or black shale were accumulating in the topographically-low Durham and Sanford basins. Similar fans have been described in the Triassic, near Reading, Pa., by McLaughlin (1939), and in the Connecticut Valley Triassic, by Krynine (1950, p. 6, 35, 192).

Data in table 5, which have been computed from stratigraphic sections measured at the outcrop or in mines and drill holes near the outcrop, show the lithology of only the exposed strata in each formation; they do not show the lithology of a vertical section through the formations at any particular spot, nor do they show the average lithology of all the sediments, exposed and not exposed, in the Deep River basin. The Pekin and

TABLE 5.—*Thickness and color of formations, and percentage distribution of conglomerate and fanglomerate, sandstone, siltstone, claystone, and shale in different parts of the Deep River basin*

Formation	Sanford basin (southwest end, vicinity of Carthage)						Sanford basin (north of Deep River fault between Gulf and Cumnock)						Colon cross structure (opposite Sanford water works)						Durham basin (south end, east side Cape Fear River)	
	Total thickness (feet)	Dark strata [1]	Congl. and fangl.	Sandstone	Siltstone	Claystone and shale	Total thickness (feet)	Dark strata [1]	Congl. and fangl.	Sandstone	Siltstone	Claystone and shale	Total thickness (feet)	Dark strata [1]	Congl. and fangl.	Sandstone	Siltstone	Claystone and shale	Total thickness (feet)	
Pekin	3,000 to 4,000	74	4	20	40	36	1,750 to 1,800	90	2	15	29	54	3,500 to 4,000	72	24	35	28	13	3,000 to 3,500	Formations not sufficiently exposed to permit detailed estimates of lithology *in this area*.
Cumnock	520	10	------	67	28	5	750 to 800	2	------	19	17	64	Not recognized in this area; grades into Pekin and Sanford formations						300 to 600	
Sanford	[2] 3,500 to 4,000	82	18	20	26	36	[2] 3,000	93	------	11	22	67	[2] 500 to 600	73	80	20	------	------	[2] 2,000 to 3,000	

[1] Percentages include red, reddish-brown, moderate or dark-brown and purple rocks. They do not include light-brown, yellow, gray or black rocks.
[2] Thickness does not include an undertermined quantity of rock removed by post-Triassic erosion.

Cumnock formations, which crop out only in the northwestern part of the basin, are deeply buried along the southeastern side, and their lithologic character in that part of the basin can only be inferred. It is probable that both of these formations become coarser toward the southeast and follow the pattern of textural change observed in the Sanford formation. The proportions of sandstone, conglomerate, and fanglomerate in the Pekin and Cumnock formations southeast of the outcrop are probably considerably higher than they are along the outcrop, and these lower formations are, therefore, coarser on the average than is indicated by the data in table 5.

In the Pekin and Sanford formations the percentage of dark-colored rocks (red, reddish-brown, moderate- or dark-brown, and purple) is inversely proportional to the coarseness of the strata, and it is highest where the percentage of conglomerate and sandstone is lowest, as shown in table 5. This results from the fact that these dark colors are provided largely by the fine detritus, which commonly contains several percent of red or brown ferric oxide. As the grain size increases, the proportion of the fine, dark detritus diminishes, and the color of the rock becomes lighter. Most of the coarse sandstone and conglomerate is composed of relatively fresh rock debris, which is light-colored; it is only where the constituent rock materials have been intensely weathered, either before or after deposition, that the coarser sediments are also dominantly dark. Small amounts of red or brown pigment make the light-colored rocks in these formations typically grayish-orange pink (10R8/2 or 5YR7/2), pale red (10R6/2), or very pale orange (10YR8/2).

In the Cumnock formation, the percentage of red or brown rocks is directly proportional to the coarseness of the strata. The predominant gray and black colors of this formation do not result from a reduction in the amount of fine detritus, but instead, the colors result from the reduction to a ferrous state of any ferric oxide that may have originally been in this detritus. Green pigment provided by this ferrous oxide gives distinctive colors to the Cumnock strata such as light greenish-gray (5GY8/1), greenish-gray (5GY6/1), light olive-gray (5Y6/1), and olive-black (5Y2/1).

Thicknesses of the Triassic formations (shown in table 5) change considerably in different parts of the Deep River basin. Differences in the thicknesses of the Pekin and Cumnock formations are a result of lateral changes in sedimentation; differences in thickness of the Sanford formation are mainly a result of post-depositional faulting and erosion. The combined thickness of the Triassic formations along the southeastern side of the Triassic sedimentary wedge totals 7,000 to 8,000 feet in the Sanford basin, 4,000 to 5,000 feet in the Colon cross structure, and at least 6,000 feet at the south end of the Durham basin. These thicknesses cannot be calculated accurately because of uncertainty as to the continuity of dips and thicknesses of strata with depth. Campbell and Kimball (1923, p. 44) estimated that the total thickness of the Triassic sediments in the Deep River field is 7,000 to 8,000 feet. Prouty (1931, p. 484) estimated that the maximum thickness of Triassic sediments in the center of the Durham basin is about 10,000 feet.

PETROGRAPHY

FANGLOMERATE

As defined and used in this report the term "fanglomerate" refers to a relatively unsorted, poorly-bedded deposit of rock debris, at least a tenth of which consists of rock fragments more than 8 cm in diameter. Most fragments in the deposit are angular or subangular. Fanglomerate commonly grades into conglomerate, which is generally better sorted, better bedded, and composed of smaller, more rounded fragments. The fanglomerate, as mapped and as shown on plate 1, however, includes lenticular beds of relatively fragment-free sandstone and siltstone and local beds of conglomerate.

Fanglomerates are present in most of the eastern Triassic basins. They have been interpreted as deposits that accumulated in alluvial fans along Triassic fault scarps that formed the edges of the basins. Krynine (1950, p. 95) has defined the fanglomerates of the Connecticut Valley Triassic as follows:

> * * * These rudely bedded sediments form the upper apex of the numerous Triassic alluvial fans that radiate westward from the (border) fault. Inasmuch as these fanglomerates gradually pass into conglomerates, it is necessary to draw some empirical dividing line between these two rock types. The term fanglomerate will be restricted to a rock in which at least 50 percent of the pebbles are decidedly angular and possess sharp edges. Lack of sorting and lack of sizing usually go hand in hand with extreme and widespread angularity of the constituents.

Discussing the Triassic of the Durham basin, Prouty (1931, p. 479) stated:

> * * * In places the border conglomerates occur with such huge and angular rock fragments mixed in the red sandstone matrix as to compel one to believe in their landslide origin. Such areas correspond to the fanglomerates of the Connecticut Valley Triassic.

In the Deep River basin, fanglomerate is present in a nearly-continuous belt, as much as 2½ miles wide, bordering the Jonesboro boundary fault (shown on pl. 1) along the southeastern side of the basin. This belt includes the highest and youngest deposits in the Deep River Triassic. Fanglomerate occupies almost all stratigraphic positions in the Sanford formation in the vicinity of Sanford near the southeast border fault, and fanglomerate probably is present also in the deeply buried strata of the underlying formations along this fault. The fanglomerate generally grades northwestward into finer-grained and more regularly bedded sediments, but in the northeastern part of the mapped area sinuous channels of fanglomerate have been observed separating the finer sediments. East of Sanford, the fanglomerate belt appears to truncate the underlying conglomerate beds of the Pekin formation, and it seems that the conglomerate beds had been tilted before the fanglomerate was deposited.

Deposits in the fanglomerate belt range from jumbled accumulations of rock fragments with very little sandstone matrix (as shown in fig. 10) to scattered, isolated blocks embedded in a more predominant sandstone matrix (as shown in fig. 11). In one extreme, the matrix consists of unsorted angular rock chips filling interstices between the larger fragments; matrix and fragments are nearly the same color—usually shades of gray or brown with a variable amount of green pigment depending on the amount of chloritic debris in the deposit. In the other extreme, the matrix is usually higher in quartz, considerably redder, relatively better sorted, and imperfectly bedded. The fanglomerate usually shows little or no bedding, but locally the materials are arranged in fairly distinct beds (as shown in fig. 12). Such materials are usually better sorted and better rounded than the average.

Fragments of all the pre-Triassic metamorphic and igneous rocks exposed southeast of the Deep River basin are contained in the Triassic fanglomerate. Northeast of the Cape Fear River, boulders of granite, apparently derived from the Carboniferous(?) granite adjoining the basin, become increasingly abundant (see pl. 1). East of Corinth, the fanglomerate is composed almost entirely of granitic debris. West of the Cape Fear River, the constituents of the fanglomerate are mainly metamorphic rock fragments.

The maximum diameters of the largest fragments observed in different parts of the fanglomerate belt are plotted on the lithologic map (pl. 4). These figures show that the fanglomerate east of the Cape Fear River contains larger blocks than the fanglomerate farther west. The largest block observed in the mapped area is about 4 feet wide; blocks as large as 8 feet wide have been reported farther north in the Durham basin. The

FIGURE 10.—Fanglomerate in Sanford formation 3 miles east of Carthage. Exposure on east side of road between Carthage and Cameron, 200 feet from Jonesboro fault. Most blocks are fragments of metamorphosed acid volcanic rocks.

size distribution per square foot of exposed fragments in two typical outcrops of relatively fine-grained fanglomerate is as follows:

Number, size, and roundness of fragments per square foot of two typical fanglomerate exposures

Average number of fragments	Maximum diameter (cm)	Average roundness of fragments	Composition
Exposure in gulley, west side Little Lick Creek, 2 miles north of Williams Lake, 1 mile from Jonesboro fault			
1	12	Angular	Schist.
2	8–10	Subangular	Quartz and schist.
3	5–8	do	Do.
24	2½–5	Subrounded	Do.
30	1–2½	do	Mainly quartz.
Over 30	½–1	Subangular	Quartz and schist.
Exposure on creek two-thirds of a mile northwest of Chestnut Church, 650 feet from Jonesboro fault [One block, 40 cm wide, in this exposure]			
1	8–10	Subangular	Schist.
2	5–8	Angular	Do.
6	2½–5	Subangular	Do.
20	1–2½	do	Do.
60	½–1	do	Do.

Although angularity is a characteristic of rock fragments in the fanglomerate, subrounded and rounded fragments are not uncommon. It is likely that much of the angularity is a result of breakage in transport. This is suggested by the many fractured blocks in the deposits and also by the fact that the fragments of friable schist or gneiss are usually more angular than the harder fragments of quartz.

CONGLOMERATE

Unlike the fanglomerate deposits, most of the conglomerate is in well-defined lenses or beds. Rocks classed as conglomerate contain pebbles 2 mm or more in diameter, in sufficient quantity to constitute a fourth of the rock or more, but the conglomerate beds shown on plate 1 include lenses of relatively pebble-free sandstone. Some beds of conglomerate, particularly those in the Colon cross structure, contain scattered boulders at least 12 inches across. The pebbles, cobbles, and boulders generally show considerable wear and are mostly subrounded or rounded; smaller rock particles forming the matrix are generally more angular. Sizing of the rock debris in the conglomerate is more consistent than it is in the fanglomerate.

The basal conglomerate of the Pekin formation is the most extensive conglomerate bed in the mapped area. As shown on plate 1, this conglomerate crops out

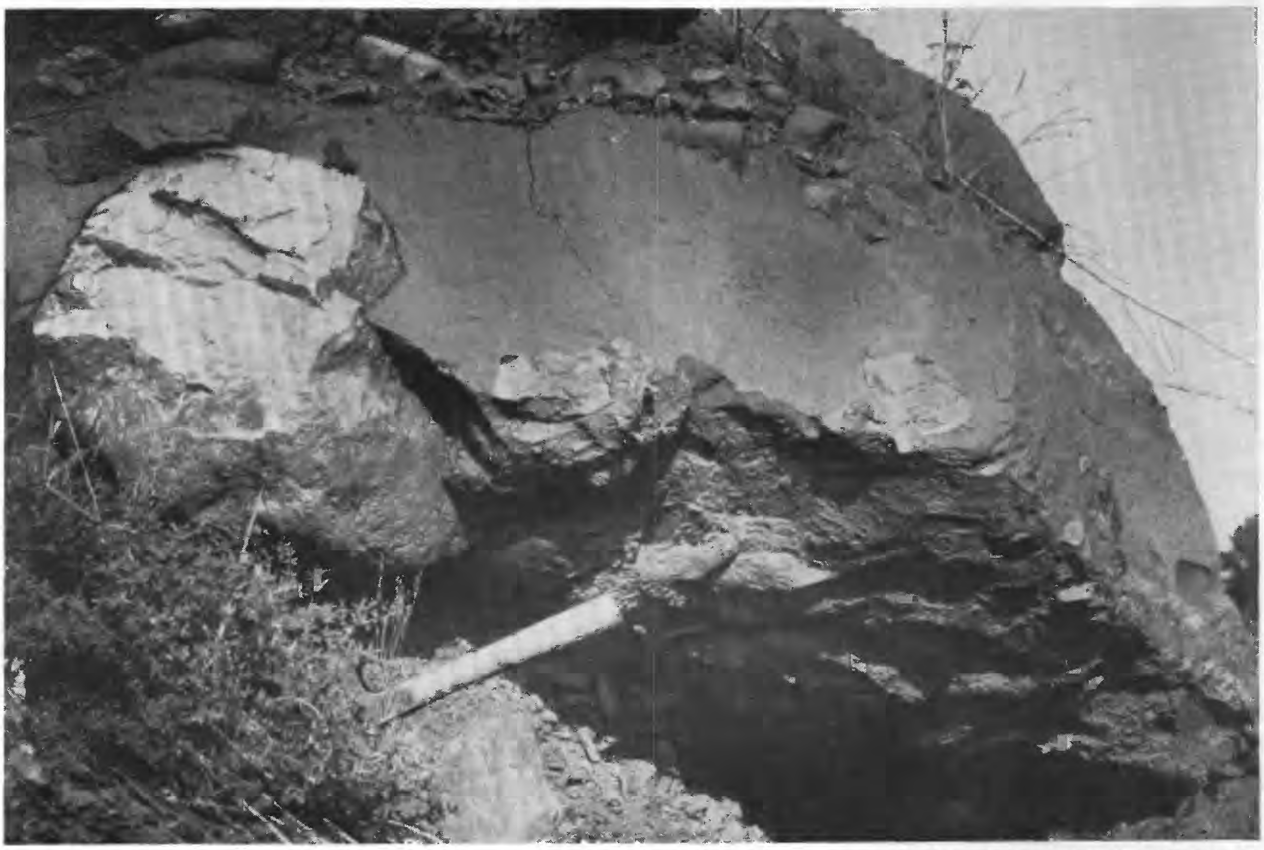


FIGURE 11.—Fanglomerate in Sanford formation, 1 mile west of Corinth. Exposure on north side of Norfolk Southern Railroad, 5,000 feet from Jonesboro fault. Large quartzite boulder has 21-inch maximum diameter; matrix is reddish-brown sandstone.

FIGURE 12.—Fanglomerate in Sanford formation, 1 mile west of Corinth. Exposure on north side of Norfolk Southern Railroad, 5,000 feet from Jonesboro fault. Rock debris derived from quartzites, granites, nonmicaceous acid volcanic rocks, micaceous schists and gneisses.

almost continuously along the northwestern edge of the Deep River basin, except where interrupted by faults. Conglomerate constitutes almost a fourth of the Pekin formation in the Colon cross structure, where the conglomerate beds grade both toward the east and toward the west into finer sediments. Widely scattered lenses of conglomerate are present in the Sanford and Pekin formations in the northwestern parts of the Sanford and Durham basins. Conglomerate is abundantly distributed through the Sanford formation in the southeastern part of the Sanford basin, where the conglomerate beds grade southeastward into the fanglomerate along the Jonesboro border fault and northwestward into conglomeratic sandstone.

Deposits at the base of the Pekin formation are a heterogeneous assemblage of cemented and uncemented masses of conglomerate containing local lenses of conglomeratic and coarse-grained sandstone. In grain size, composition, color, and thickness this basal conglomerate changes abruptly along the outcrop, with the result that the appearance of the deposit is entirely different in different parts of the basin. This variation in appearance is related to differences in the source rocks from which the conglomerate was derived.

North and west of Moncure, and west of Carthage, the basal conglomerate and associated sandstone lenses of the Pekin formation are composed mainly of uncemented debris from the light-colored acid volcanic tuff exposed northwest of the Triassic basin. Pebbles, cobbles, and boulders are mainly grayish-pink, grayish-orange, pale red, or pale brown, subrounded to well-rounded fragments of relatively fresh but loosely coherent tuff. Quartz pebbles form only a small proportion of the total deposit. Figure 13A shows the disposition of fragments in a typical exposure of conglomerate on the eastern side of Deep River north of Moncure. Matrices and sandstone lenses consist of highly feldspathic tuffaceous debris, partly fresh and partly decomposed, mixed with variable amounts of dark-red, dark-brown, or purple quartz sand and clay derived from weathering of the pre-Triassic rocks. Some of the fresh, even-grained sandstone in this deposit resembles the parent acid tuff. Lenses of micaceous sandstone and light-gray clay have also been observed north of Moncure. An exposure of the basal conglomerate deposit in this area is shown in figure 14.

In the vicinity of Glendon the basal conglomerate of the Pekin formation consists mainly of uncemented

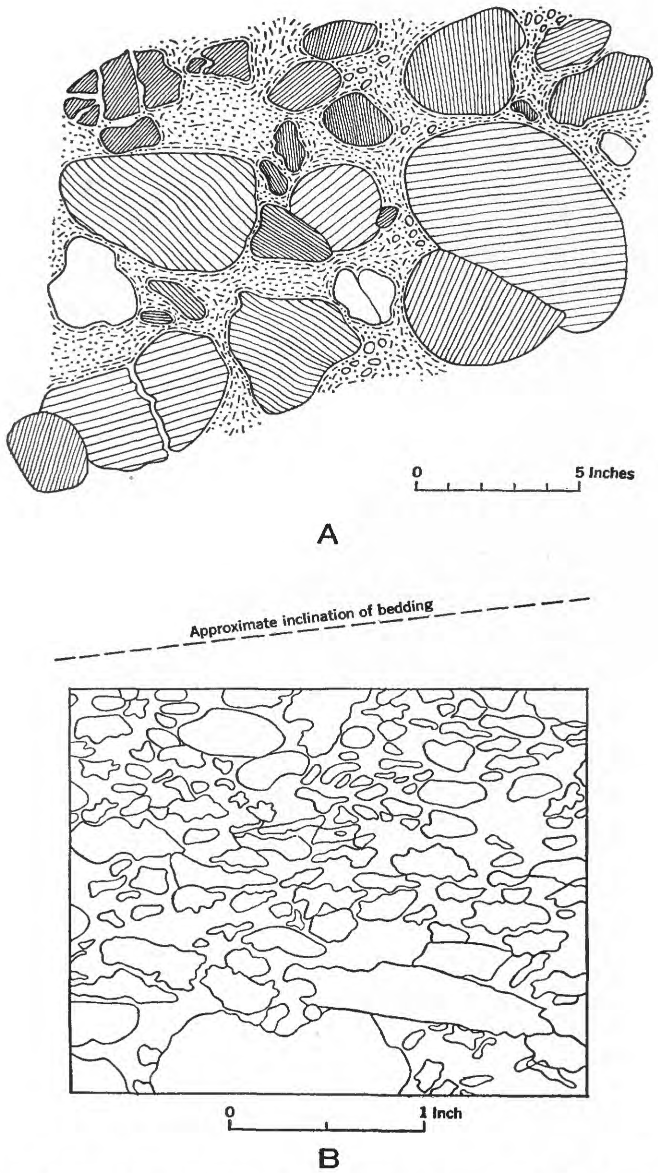


FIGURE 13.—*A*, Sketch showing texture of conglomerate at base of Pekin formation, east side of Deep River at Lockport. Lined fragments are mainly schistose tuff, unlined fragments are quartz; matrix is feldspathic, tuffaceous debris mixed with quartz sand and clay. *B*, Sketch showing texture of conglomerate in lower part of Sanford formation in drill hole BMDH DR–2. Fragments are siltstone; matrix is coarse-grained micaceous sandstone.

debris from the pre-Triassic slate that borders the Triassic basin. The lowest beds are composed of angular or subangular fragments of the slate on which they rest, as shown in figure 15. Higher beds in the basal conglomerate in this area contain debris from other pre-Triassic rocks exposed farther north.

North and east of the Carolina mine, and east and south of Putnam, the basal Triassic deposits consist, in part, of a firmly cemented quartz conglomerate. This rock is composed mainly of subangular, or subrounded, gray, pink, or colorless quartz pebbles as much as 3 inches across, and less abundant fragments of tuff and other pre-Triassic rocks, embedded in a quartz-cemented, dark yellowish-brown (10YR4/2) sandstone matrix. The matrix consists mostly of quartz, quartzite, quartz-sericite schist, and quartz-biotite-magnetite schist grains. The average composition and roundness of grains in this matrix, as determined by microscopic examination of thin sections of this rock, is as follows:

Average distribution and roundness of granular constitutents in matrix of "millstone grit" quartz conglomerate at base of Pekin formation

Granular constituents	Percentage distribution	Roundness of grains [1]
Quartz	11	20
Quartzite	31	35
Quartz-sericite schist	25	45
Quartz-biotite-magnetite schist	24	50
Other (sericite, biotite, magnetite, olivine, augite, epidote, apatite)	9	0–43

[1] Roundness is given on a scale of 0–100, where 0 is angular and 100 is well-rounded.

Because of its hardness, this quartz conglomerate was formerly used for millstones and came to be known as the "millstone grit." It was quarried at several localities east and south of Putnam, but it was obtained mainly at the "Millstone grit quarry," shown on plate 1, about a mile south of Hallison. The individual conglomerate beds are commonly 3 to 6 feet thick, separated by less-indurated beds of conglomeratic sandstone, which facilitate the extraction of the rock. At Friendship Church, east of Hallison, the millstone grit is about 30 feet thick, and it is probably at least as thick in the Millstone grit quarry, which is now flooded. On the highway between these localities, this grit forms a lens only 6 feet thick, shown in figure 16. At that locality, it is overlain and underlain by uncemented conglomerate and sandstone resembling the basal deposits north of Moncure; the lateral distribution of the millstone grit is shown on plate 4. The average grain size distribution of this quartz conglomerate, based on studies of hand specimens and thin-sections, is as follows:

Average grain size distribution of "millstone grit" quartz conglomerate at base of Pekin formation

Size (in millimeters)	Percent
64–32	3
32–16	19
16–8	27
8–4	12
4–2	16
2–1	6
less than 1	17
	100

FIGURE 14.—Conglomerate near base of Pekin formation, 1 mile north of Moncure. Exposure on east side of county road along Seaboard Railroad, 275 feet above base of Triassic. Pebbles and cobbles are pink and gray tuff fragments; matrix is gray and purple tuff debris.

Quartz-cemented conglomerate resembling the mill-stone grit is present about a mile southeast of Horse Shoe Bridge (see pl. 1) and a mile north of Sanford, in the lower part of the Sanford formation, and at many other localities in both the Sanford and Pekin formations. However, most conglomerate in these formations has a higher proportion of schist fragments and is less indurated. Conglomerate beds in the Colon cross structure are typically dark-gray or purplish; those in the Sanford basin are usually red or brown.

Beds of conglomerate in the middle of the Sanford formation exposed near Carthage contain abundant pebbles of red siltstone. These pebbles are extremely friable and probably were not transported far; they may be fragments of previously-deposited Triassic siltstone. A similar conglomerate was found in the Sanford formation in drill hole BMDH DR–2; the texture of this rock is shown in figure 13 *B*. Pebbles 1 mm or more in diameter constitute about 84 percent of this conglomerate. They are very dusky red (10R2/2) or grayish-red (5R4/2) in color, and range from angular to well-rounded; most are subrounded or rounded. Microscopic examination shows that these pebbles consist mainly of muscovite, biotite, and epidote fragments, and scattered grains of quartz and pyrite, in a chloritic, hematitic matrix. The pebbles are embedded in a light greenish-gray (5GY8/1 to 5G8/1) or greenish-gray (5GY6/1) quartz-cemented sandstone. The average composition and roundness of the granular constituents of this sandstone groundmass are as follows:

Average distribution and roundness of granular constitutents in matrix of siltstone-pebble conglomerate in Sanford formation in drill hole BMDH DR–2

Granular constituents	Percentage distribution	Roundness of grains [1]
Quartz	41	30
Quartzite	27	45
Muscovite-biotite-chlorite	21	25
Feldspar	4	5
Olivine-augite	5	45
Other (apatite, magnetite, hematite)	2	50–75

[1] Roundness is given on a scale of 0–100 where 0 is angular and 100 is well-rounded.

The average grain size distribution of this siltstone pebble conglomerate as determined by microscopic and megascopic examination of the drill core is as follows:

FIGURE 15.—Conglomerate at base of Pekin formation ½ mile north of Glendon. Exposure at south end of Glendon Bridge. Pre-Triassic slate (lower left) overlain by basal Triassic deposits (upper right) consisting mainly of slate chips. Irregular basal Triassic contact is indicated by hammer.

Average grain size distribution of siltstone-pebble conglomerate in Sanford formation in drill hole BMDH DR-2

Size (in milimeters)	Percent
64–32	29
32–16	15
16–8	22
8–4	13
4–2	4
2–1	1
Less than 1	16
	100

SANDSTONE

Sandstone consists mostly of particles from 1/16 mm to 2 mm in diameter. Coarse-grained sandstone commonly contains scattered pebbles more than 2 mm across and grades into conglomeratic sandstone and conglomerate. Fine-grained sandstone commonly contains large amounts of detritus in particles less than 1/16 mm across and grades into siltstone, claystone, and shale.

All the Triassic formations contain important amounts of sandstone; the distribution of sandstone in the Deep River coal field is shown on the lithologic map (pl. 4). In general, sandstone is most abundant in the Colon cross structure and along the southeast side of the Durham and Sanford basins. In the Pekin and Cumnock formations, the sandstone is more abundant in the southwestern part of the Sanford basin than in the northeastern part; in the Sanford formation, sandstone is more abundant in the northeastern part of this basin. The fine-grained sandstone of the Pekin and Sanford formations is mostly dark-brown or red, whereas the medium- and coarse-grained sandstones in these formations are typically light shades of gray, yellow, brown, orange, purple, or green. Practically all sandstone in the Cumnock formation is gray or black.

Sandstone deposits in the Deep River Triassic may be grouped roughly into three categories on the basis of composition: arkose, schist-arenite, and argillaceous sandstone. Arkose consists of debris derived mainly from the Carboniferous(?) granite or, locally, from pre-Triassic acid volcanic rocks. Schist-arenite consists of debris derived mainly from the pre-Triassic metamorphic rocks. Argillaceous sandstone consists of debris derived from either the Carboniferous(?)

FIGURE 16.—Conglomerate near base of Pekin formation, 1 mile southeast of Hallison. Exposure on east side of State Highway 22, 100 feet above base of Triassic. Lens of gray quartz-cemented conglomerate ("millstone grit") surrounded by brown, or purple, uncemented arkosic sandstone and conglomerate.

granite or the pre-Triassic metamorphics, mixed with hematitic clay produced by the weathering of these rocks or with large amounts of non-quartzose, nonfeldspathic debris from more basic rocks. The composition, distribution, and properties of these three types of sandstone are summarized below.

Basic types of sandstone in the Deep River coal field

A. Arkose.

1. Source: Carboniferous(?) granite.
   - Distribution: Upper part of Sanford formation along Jonesboro border fault, south end of Durham basin (very local).
   - Composition: Total quartz and feldspar form 80 percent or more of rock (feldspar 25 to 70 percent and metamorphic rock fragments generally less than 10 percent).
   - Color: Yellowish-gray, pinkish-gray, very pale orange.
   - Texture: Coarse-grained or medium-grained; locally resembles granite.
   - Cement: Locally calcite; mostly uncemented.
   - Bedding: Irregular; crossbedding common.
   - Forms: Mainly as channel deposits cutting other sediments.
2. Source: Pre-Triassic metamorphosed acid volcanic rocks.
   - Distribution: Lower part of Pekin formation north and west of Moncure and northwest of Carthage (very local).
   - Composition: Total quartz and feldspar form 80 percent or more of rock (feldspar 25 percent or a little more and metaporphic rock fragments generally less than 25 percent).
   - Color: Grayish-orange pink, very pale-orange, light-brown.
   - Texture: Medium-grained or fine-grained; locally conglomeratic.
   - Cement: Mainly quartz.
   - Bedding: In part irregular, crossbedded; in part regular in beds a few inches thick.
   - Forms: In beds and irregular lenses; a few channel deposits.

B. Schist-arenite.

1. Source: Granite and pre-Triassic metamorphic rocks.
   - Distribution: Upper part of Sanford formation gradational into type A–1 (above) and lower part of Pekin formation gradational into type A–2 (above). Present locally in Sanford formation in Sanford basin (local).
   - Composition: Total quartz and feldspar form 80 percent or more of rock (feldspar 15 to 25 percent and metamorphic rock fragments generally 10 to 25 percent).
   - Color: Yellowish-gray, light greenish-gray, grayish-orange.
   - Texture: Coarse-, medium-, or fine-grained, mostly coarse.
   - Cement: Partly quartz, partly uncemented.
   - Bedding: Mostly irregular, crossbedded.
   - Forms: In beds, lenses, and channel deposits.

2. Source: Pre-Triassic metamorphic rocks.
   Distribution: In all formations, especially in lower and middle Pekin, lower and middle Sanford in Sanford basin; includes most sandstone in Colon cross structure (extensive).
   Composition: Total quartz and feldspar form 80 percent or more of rock (feldspar less than 15 percent and metamorphic rock fragments 25 to 75 percent).
   Color: Light-colored shades of gray, yellow, brown, orange, purple, or green.
   Texture: Coarse-, medium-, or fine-grained, mostly coarse.
   Cement: Partly quartz, mostly uncemented.
   Bedding: Mostly irregular, crossbedded.
   Forms: In channel deposits and in "blanket-type" beds several miles across.

C. Argillaceous sandstone.
   Source: Granite and pre-Triassic metamorphic rocks, including soils developed from these rocks.
   Distribution: In all formations; includes most sandstone in the lower and upper parts of the Pekin and Cumnock and in the middle part of the Sanford formations in Sanford and Durham basins (very extensive).
   Composition: Total quartz and feldspar form less than 80 percent of rock (feldspar less than 15 percent, metamorphic rock fragments generally 25 to 50 percent and clay minerals, micas, iron ores and oxides, olivines-pyroxenes, and rare minerals more than 20 percent).
   Color: Gray or black in Cumnock formation; dark-brown or red in Pekin and Sanford formations.
   Texture: Fine-grained to clayey; grades into siltstone and claystone.
   Cement: Partly quartz; clay acts as a bond.
   Bedding: Mostly regular; locally crossbedded.
   Forms: Generally in beds from a few inches to several feet thick.

Arkose forms considerably less than a tenth of the sandstone in the mapped area. It is present almost exclusively in the Durham basin, mainly in parts of the basin bordered by the Carboniferous(?) granite. Arkose grades longitudinally (along the basin) into schist-arenite by admixture of feldspar-deficient metamorphic rock debris, and it grades laterally (across the basin) into argillaceous sandstone by admixture of clay, micas, and other fine detritus. Arkose is well exposed near Corinth, but much better exposures are present farther northeast in the Durham basin.

Most of the medium-grained and coarse-grained arkosic sandstones in the mapped area are schist-arenites rather than true arkoses. These rocks are characterized by a relative deficiency (less than 25 percent) in feldspar and by a high content of metamorphic rock fragments, chiefly quartzite and quartz-sericite schist. Though typically light-colored, sandstone of this type in the Pekin and Sanford formations grades laterally and longitudinally into dark-brown or red argillaceous sandstone with admixture of hematitic clay, micas, olivine and pyroxene, iron ores, and other non-feldspathic and non-quartzose detritus. Compositions and size-frequency distributions of typical schist-arenite and argillaceous sandstone, determined by microscopic study of thin-sections, are listed in table 6. Specimens 1 and 2 are schist arenite, 3 and 4 are transitional to argillaceous sandstone, and 5, 6, and 7 are argillaceous sandstone; photomicrographs of specimens 3 and 4 are shown in figures 17 and 18. The locations of these specimens are as follows:

1. Sanford formation, drill hole BMDH DR–1, depth about 1,240 feet.
2. Sanford formation, creek ½ mile southwest of Cumnock, west side Deep River.
3. Sanford formation, old quarry near U. S. Highway 421, ½ mile east of Gulf. Probably the same bed as specimen no. 2.
4. Sanford formation, creek 1 mile north of Sanford, 800 feet west of U. S. Highway 1.
5. Pekin formation, on Norfolk Southern Railroad 5 miles north of Sanford, ½ mile west of U. S. Highway 1.
6. Sanford formation, drill hole BMDH DR–2, depth about 1,450 feet. Sandstone associated with siltstone-pebble conglomerate previously described.
7. Sanford formation, from old quarry on west edge of Sanford "Brownstone" used in construction of public buildings in Sanford.

Schist-arenite occupies narrow, sinuous channel deposits and broad "blanket-type" beds. Basal contacts of these deposits are very irregular, as shown in figure 19–A. The deposits are generally conglomerate at the bottom; commonly they contain irregular fragments of the underlying sediment. The best exposures of schist-arenite beds in the Sanford formation are in the clay pit of the Chatham Brick and Tile Company and in the old sandstone quarries southeast of Gulf. The best exposure of a schist-arenite in the Pekin formation is in the Pomona Terra Cotta Company clay pit near Gulf.

Constituent schist-arenite grains show no appreciable rounding. Under the microscope, these rocks appear as a mosaic of angular, non-oriented grains as shown in figures 17 and 18. Locally, the rocks are cemented with quartz, but generally they are held together only by an interlocking of the grains (caused apparently by post-depositional compaction, and facilitated by the angularity of the grains and the high content of easily-deformable schist fragments). Less than a tenth of the feldspar grains in these rocks are extensively altered, but about half are slightly altered.

Some of the medium-grained and coarse-grained sandstone and most of the fine-grained sandstone in the Deep River Triassic are classed as argillaceous. Argillaceous sandstone is characterized by a lower content (less than 80 percent) of total quartz and feldspar than in the other types of sandstone. In some sandstone the decrease in quartz-feldspar content is accompanied by an increase in olivines, pyroxenes, and iron

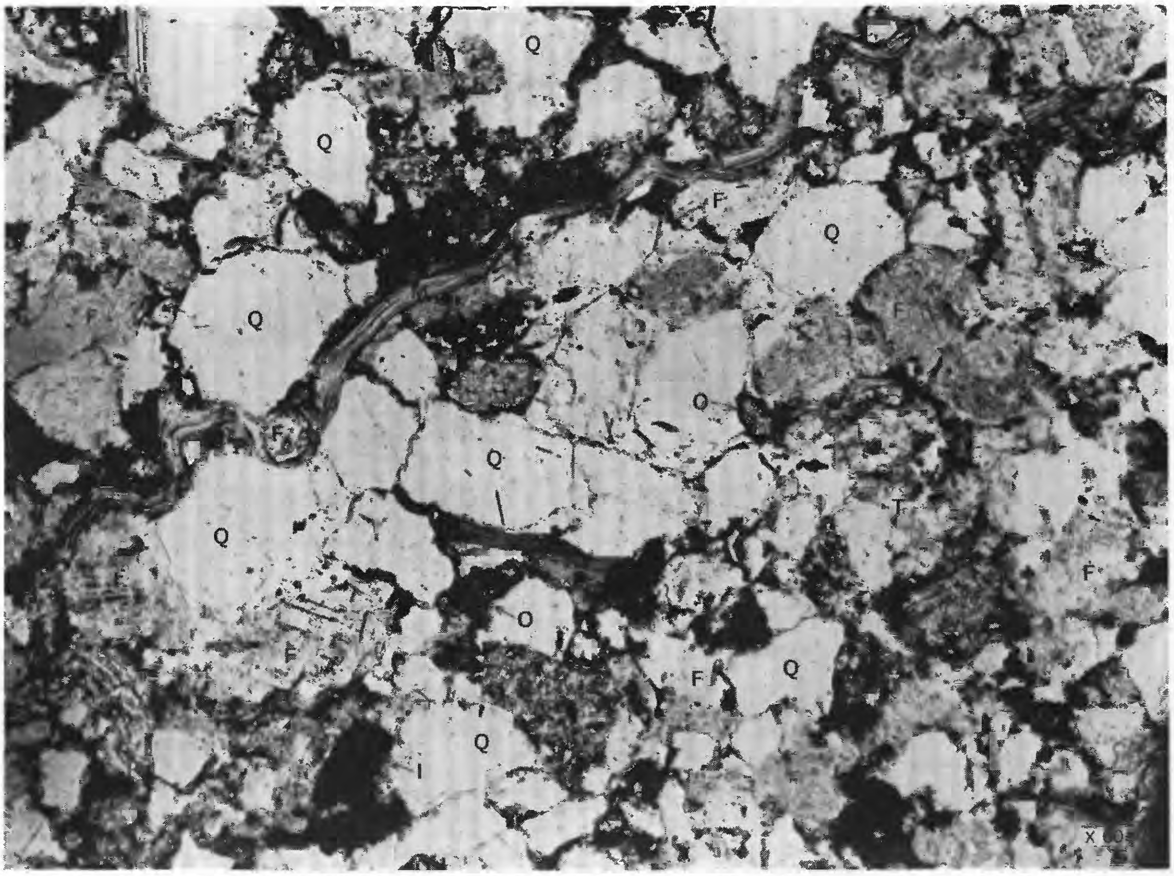


FIGURE 17.—Photomicrograph of schist-arenite from Sanford formation ½ mile east of Gulf. Thin section of specimen no. 3 listed in table 2. Enlarged 60 times. Nonpolarized light. Q—quartz; F—feldspar; M—muscovite; B—biotite; O—olivine; I—ilmenite; T—titanite.

ores probably derived from basic igneous rocks. In other sandstones, this decrease is accompanied by an increase in content of clay minerals probably derived from the weathering of the pre-Triassic rocks.

Under the microscope, argillaceous sandstone looks like "dirty" schist-arenite. The grains commonly are bordered by hematite. Detritus between the grains consists mainly of clay minerals, sericite, chlorite, olivines and pyroxenes, magnetite, ilmenite, and hematite. Scattered large grains of iron ores, olivines, and micas are present in some of the rocks.

Under the microscope, argillaceous sandstone looks bedded than other types of sandstone, but locally it also forms irregular channel deposits. It is generally finer-grained than either schist-arenite or arkose (see table 6). Sandstone of this type in the Pekin and Sanford formations is typically dark-brown or red, because of the hematite coatings on the grains or the hematitic clay matrix. Triassic "brownstone" of this type has been used for construction; specimen 7, listed in table 6, is a typical "brownstone" from a quarry near Sanford. Argillaceous sandstone in the Cumnock formation is gray to black; it was probably deposited in a moist environment containing abundant organic material, which resulted in the reduction of the dark-brown or red ferric oxide (mostly hematite) to colorless ferrous oxide.

The relationships of argillaceous sandstone to schist-arenite and arkose and to the finer clastics are indicated in figure 20. The compositions of specimens listed in table 6 are also plotted in this diagram. As shown in this illustration, argillaceous sandstone grades into siltstone, claystone, and shale with an increase in the content of clay and other minor constituents, accompanied by a decrease in grain size. Argillaceous sandstone corresponds in composition and in some physical properties to graywracke and subgraywracke. Schist-arenite corresponds in composition to arkosic or feldspathic quartzite, but because of the high content of metamorphic rock fragments, the term schist-arenite seems more appropriate. This term has been applied previously by Krynine (1937, p. 427)[4] to similar rocks in the Siwalik series of India.

[4] Krynine applies the term schist-arenite, first proposed by Professor Knopf, to rocks with an average content of 40 percent quartz, 15 percent feldspar, 6 percent mica, and 35 to 40 percent metamorphic rock fragments.

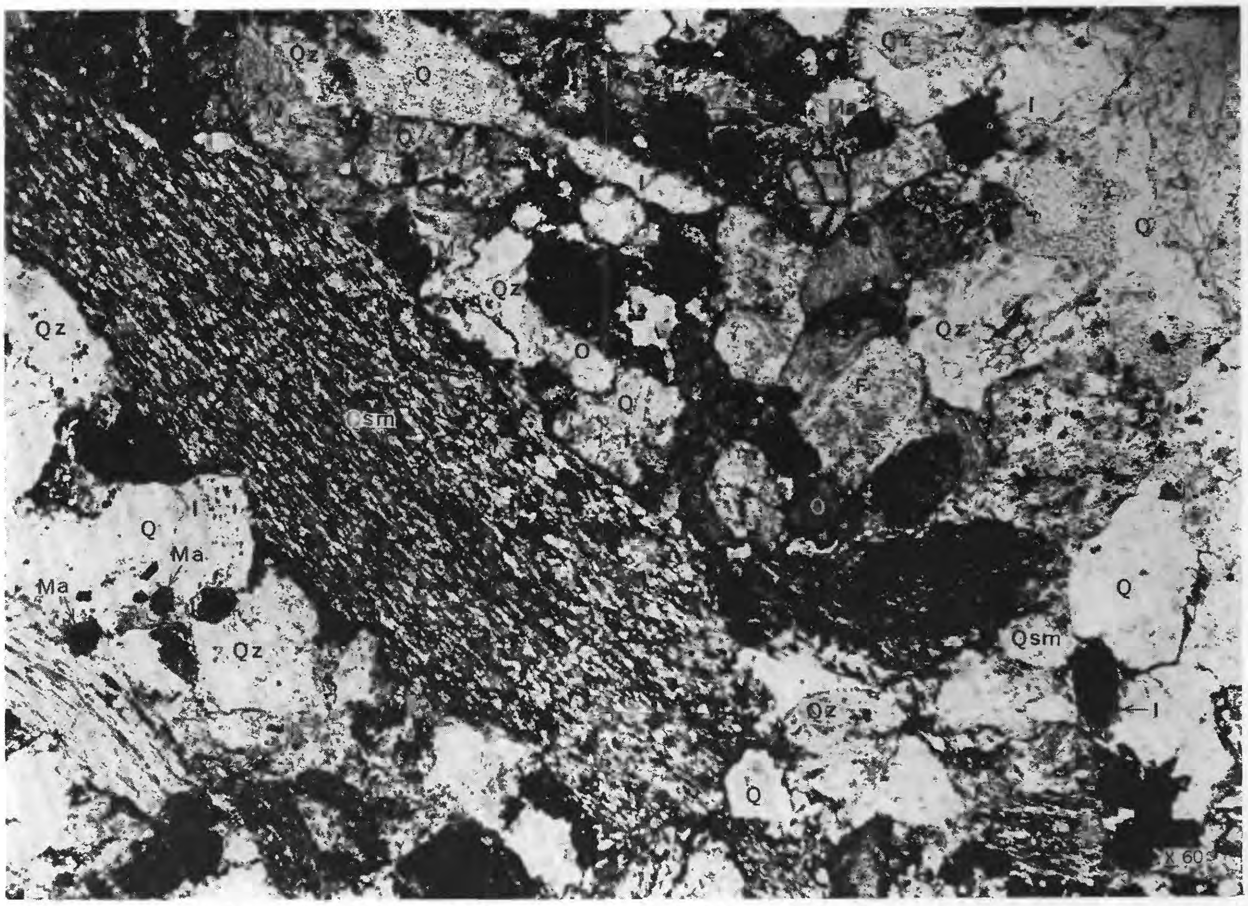


FIGURE 18.—Photomicrograph of schist-arenite from Sanford formation 1 mile north of Sanford. Thin section of specimen no. 4 listed in table 2. Enlarged 60 times. Nonpolarized light. Q—quartz; F—feldspar; Qsm—quartz-magnetite-sericite schist; Qz—quartzite; M—muscovite; Ma—magnetite; O—olivine; I—ilmenite.

SILTSTONE, CLAYSTONE, AND SHALE

Siltstone is composed mostly of particles between $\frac{1}{16}$ mm and $\frac{1}{256}$ mm in diameter. It is distinguished from claystone by superior hardness, greater resistance to erosion, and distinctly granular or "sugary" appearance when observed through a hand lens. Siltstone may be regarded as very fine grained argillaceous sandstone. It is a mixture of quartz, clay minerals, sericite, chlorite, iron oxides, and other finely comminuted rock debris. With increasing coarseness, and increasing quartz-feldspar content, it grades into argillaceous sandstone; with increasing fineness, and increasing clay mineral content, it grades into claystone.

In the Deep River Triassic, siltstone is present abundantly in all formations. Siltstone is quantitatively most abundant in the middle and upper parts of the Pekin formation and in the lower and middle parts of the Sanford formation on the northwest sides of the Sanford and Durham basins. It also is present near the top and in the lower part of the Cumnock formation in the coal-bearing part of the Sanford basin. Most of the siltstone in the Pekin and Sanford formations is grayish-red or dark reddish-brown; in the Cumnock formation it is gray or black. Most siltstone in the Pekin and Sanford formations is in fairly regular beds, ranging from a few feet to as much as 20 feet in thickness, and alternating with beds of claystone. Most siltstone in the Cumnock formation is in irregular lenses that grade laterally into sandstone, claystone, or shale within short distances. Siltstone and fine-grained sandstone in the Cumnock formation are generally calcareous, but this is not true in the other formations. Some beds of siltstone near the coal beds contain casts of plant roots and other plant fossils; some of these rocks are carbonaceous.

Claystone is composed mostly of clay minerals, and contains small amounts of sericite, chlorite, quartz, and other minerals mostly in particles less than $\frac{1}{256}$ mm in diameter. Some claystone contains widely scattered grains more than 1 mm in diameter. Claystone shows no fissility or bedding; it crumbles rapidly on exposure and instantly becomes slippery when moistened. Chemical analysis of claystone from the Pekin and Sanford formations, which are presented in the chapter

TABLE 6.—*Percentage composition and size frequency distribution of typical sandstones in the Deep River coal field*

Specimen No.	Composition																						Size frequency distribution size class in millimeters[4]								
	Principal constituents[1]							Heavy minerals[2]													Matrix[3]										
	Quartz	Feldspar	Quartzite	Quartz-sericite schist	Micas—clays	Olivine-pyroxene	Heavy minerals	Magnetite	Ilmenite	Titanite	Apatite	Rutile	Zircon	Tourmaline	Spinel	Garnet	Epidote	Staurolite	Pyrite	Cement	Detritus	Color	16-18	8-4	4-2	2-1	1-½	½-¼	¼-⅛	⅛-1/16	Less than 1/16
1	46	23	10	4	14	1	2	×	×	×××	×	----	×	----	----	----	----	----	----	Quartz (partial).	Chlorite-micas.	Green	---	---	---	---	24	28	24	6	18
2	53	14	17	8	6	1	1	××	×	×	×	×	××	×	×	----	----	----	----	do	Hematite-chlorite-micas.	Brown	---	---	6	48	24	7	2	1	12
3	39	13	24	6	10	6	2	×	×	××	×	××	×	×	----	×	----	----	----	do	Hematite-sericite-olivine (?).	do	---	---	2	3	32	37	9	2	15
4	12	5	46	24	----	7	6	×××	×	××	×	×	××	×	----	----	×	----	----	None	Hematite-micas-quartz.	do	---	15	32	14	16	5	1	1	16
5	23	----	30	36	3	5	3	×××	××	×	×	----	----	----	----	----	----	×	----	Quartz	Quartz-iron ores-sericite.	do	---	---	12	35	16	13	2	1	21
6	41	4	27	----	21	5	2	××	××	×	×	----	----	×	----	----	×	----	×	do	Chlorite-hematite-quartz.	Greenish-brown	---	---	---	---	25	37	23	9	6
7	15	11	26	28	15	2	3	×××	×	××	×	----	----	×	----	----	×	----	----	Quartz (partial).	Hematite-micas-clays.	Brown	---	---	---	1	34	25	12	1	27

[1] Quartz percentages include grains and cement but not quartz in rock fragments.
Quartz-sericite schist percentages include quartz-biotite-magnetite schist and other rocks.
Micas-clays percentages include some oxides and some unidentified debris.
[2] Heavy minerals shown as follows: ×××=50 percent or more of total heavy mineral percentage; ××=20 percent or more; ×=less than 20 percent.
[3] Detritus includes principal constituents in size fraction less than 1/16 mm.
[4] Frequency distributions based on measurements of grain parameters and calculation of grain areas in typical thin sections. The distributions are therefore volumetric and are only approximate. Granular constituents are too friable to permit accurate frequency determinations by crushing and sieving.

on clay products, show that the content of SiO_2 ranges from about 55 to 74 percent; Al_2O_3 ranges from about 11 to 25 percent, and Fe_2O_3 ranges from about 4 to 10 percent. The CaO content is generally less than 1 percent, except in some claystone in the Cumnock formation.

Claystone is present in all formations and is most abundant in the northwestern parts of the Durham and Sanford basins. Most claystone in the Pekin and Sanford formations is moderate reddish-brown; most claystone in the Cumnock formation is gray or black. Along fault zones, the reddish-brown claystone is commonly spotted with gray patches where the ferric oxide has apparently been reduced by the action of ground water. Casts resembling worm tubes are exceedingly abundant in some reddish-brown claystone, but few other fossils occur in these rocks.

Shale differs from claystone in having fissility or bedding. This may be partly a result of differences in mineral content and partly a result of differences in arrangement and orientation of mineral grains. Most of the finest clastics in the Pekin and Sanford formations are claystone, whereas most of the finest sediments in the Cumnock formation are shale. The distribution of shale in the Deep River coal field is shown on the lithologic map (pl. 4).

Shale in the Pekin and Sanford formations is mostly reddish-brown, but thin beds of gray shale are present locally in both these formations in the northeastern part of the Sanford basin. Reddish-brown, thin-bedded shale is well exposed about a mile west of Bethlehem Church in Moore County; a dark-red fissile shale is exposed on U. S. Highway 421, south of Cumnock in Lee County. The reddish-brown shale is commonly ripple-marked and micaceous and may contain rain-drop impressions, mud cracks, and plant fossils. Shale consisting of alternating gray silty laminae and red non-silty laminae was encountered in drill hole BMDH DR–2. The silty laminae grade upward into the non-silty laminae, as shown in figure 19 *C*; impressions of organic and inorganic origin on the shale surfaces are shown in figure 19 *D*.

Shale in the Cumnock formation is confined mainly to the 500 feet of this formation that overlies the coal beds; as much as 280 feet of shale is present in this formation in the northern part of the Sanford basin. About three-fourths of the shale is black and fissile, the rest is gray and thin bedded. About half of the shale is calcareous, but the calcareous content is not laterally consistent. The shale is locally silty, and some of the black shale is carbonaceous. Gray shale commonly contains plant fossils (fragments of ferns, horsetails, cycads, ginkgos, and conifers); black shale generally contains the remains of crustaceans, fish, and reptiles. The most common fossil in this shale is the small bi-

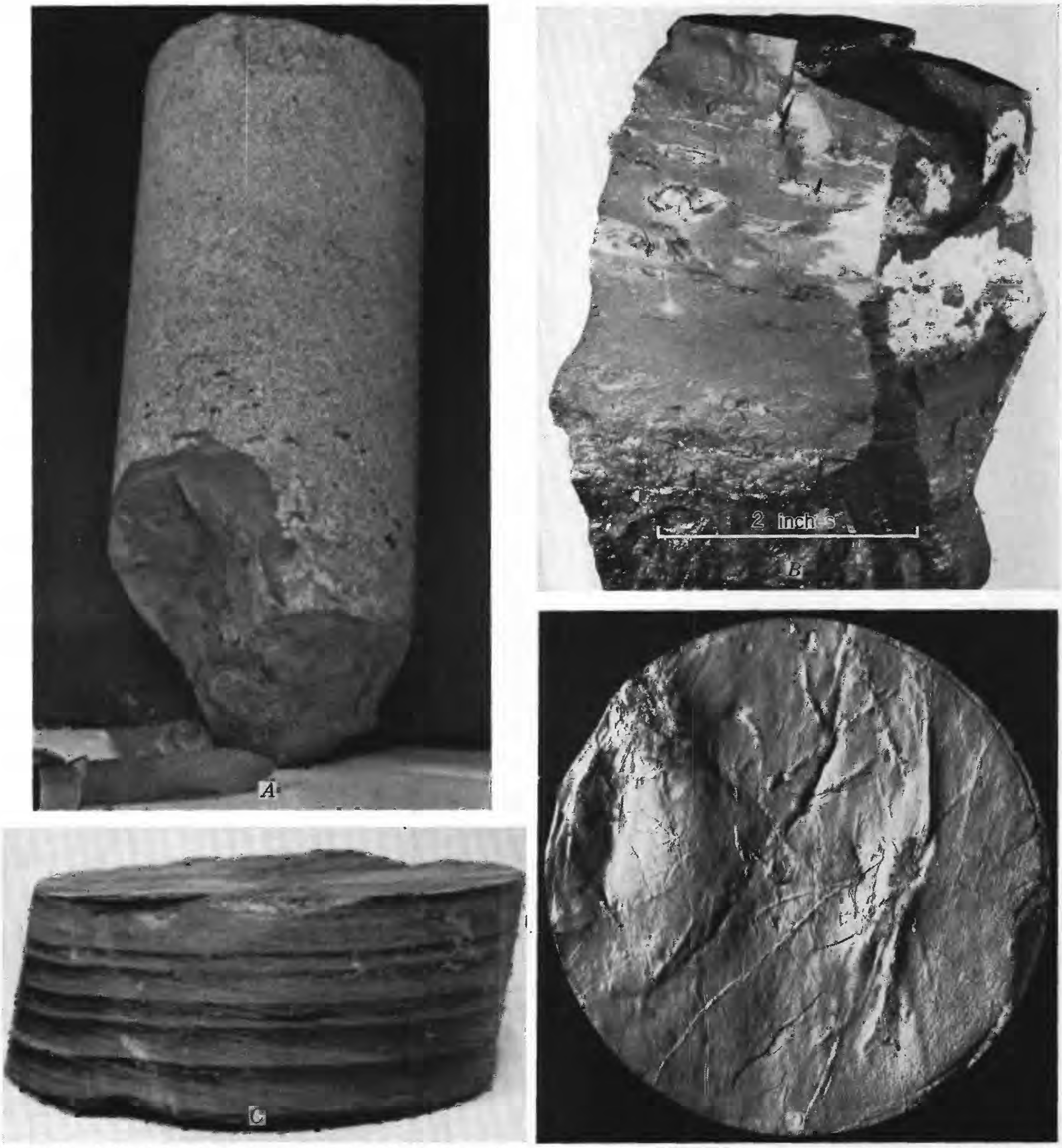


FIGURE 19.—*A*, Specimen of arkosic sandstone from Sanford formation. Conglomeratic schist-arenite resting on reddish-brown claystone, with typical irregular contact. Core from drill hole BMDH DR–1, diameter 4 inches. *B*, Specimen of blackband from Cumnock formation. Blackband resting on coal in lower bench of Cumnock coal bed. Note shiny coal blebs in blackband and white calcite fracture coatings. From Carolina mine. *C*, Specimen of shale from Sanford formation. Graded bedding with alternation of reddish-brown clay (dark) and brownish-gray silt (light). Core from drill hole BMDH DR–2, diameter 4 inches. *D*, Specimen of shale from Sanford formation. Impressions on clay bedding surface of specimen shown in *C*. Marks probably are partly of organic and partly of inorganic origin.

valved crustacean identified by J. B. Reeside, Jr. as *Cyzicus* (= *Estheria*) *ovata* (Lea). Macerated fragments of fish bones, scales, and fin-rays in cores from drill holes BMDH DR–1 and DR–2 have been assigned by D. H. Dunkle either to the genus *Redfieldia* or to the genus *Dictypyge*. Reptilian teeth in this shale were assigned by Dunkle to the phytosaur *Rutiodon*. Sketches of most of the fossils found in the Deep

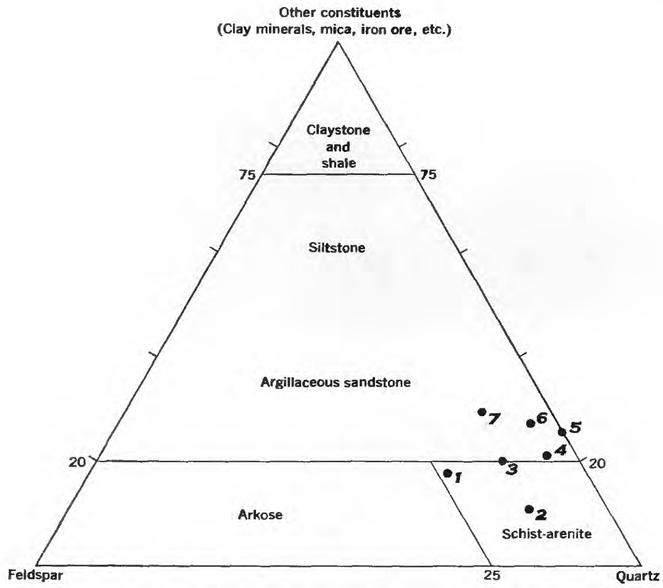


FIGURE 20.—Compositions of sandstone, siltstone, claystone, and shale in the Deep River coal field. Numbers 1–7 show comparisons of sandstones listed in table 2.

River shale have been published by Emmons (1856, pls. 1–6).

Beds of ferruginous, thick-bedded shale (known as blackband) are commonly near the coal seams. The most extensive blackband bed is between the main bench and the lower benches of the Cumnock coal bed. This bed is generally about 18 inches thick, usually has a distinctive brownish-black color or streak, and is sectile. Blebs and stringers of coal or carbonized plant debris are commonly scattered through the rock, as shown in figure 19 *B*. Blackband contains small amounts of nitrogen and phosphorous compounds, shale oil, and iron. These constituents are discussed in more detail in the chapter on black shale and blackband. Blackband beds represent accumulations of carbon and iron-rich muds in the coal-forming swamp at times of restricted accumulation of plant material.

SOURCE OF THE SEDIMENTS

The exposed beds of conglomerate and sandstone at the base of the Deep River Triassic were derived largely from the pre-Triassic metamorphic rocks west of the Deep River basin. This is indicated by the abundance of fragments of these rocks in the basal Triassic sediments and by the close correspondence between the composition of the basal Triassic sediments and the composition of the nearby pre-Triassic rocks. Crossbedded arkosic sandstone or schist-arenite channel deposits, north of Moncure and northwest of Carthage, indicate that the streams that deposited these sediments were flowing southeastward. The probable directions of current flow in these areas are shown on plate 4. Some pre-Triassic materials may have been transported a mile or more before they were deposited as part of the basal sediments in the basin; other materials, which were residual accumulations overlying the pre-Triassic rocks, were incorporated in the basal Triassic sediments practically in place.

Except for the basal Triassic deposits, most sediments in the Deep River basin probably came from the southeastern side of the basin. This is indicated by the general southeastward increase in coarseness of the sediments, by the corresponding distribution of Triassic arkose within the basin and Carboniferous(?) granite southeast of the basin, and by the existence in the Triassic of large amounts of detrital materials, such as muscovite, which are not abundant constituents of pre-Triassic rocks northwest of the Deep River basin, but which are present in exposures of the Wissahickon schist southeast of the basin. Crossbedding in sandstones in the Sanford formation and upper part of the Pekin formation also shows that the streams that deposited these sediments were flowing toward the north or northwest. Probable directions of current flow, at points where determinations have been made, are shown on plate 4. These lithologic features of the Triassic sediments indicate that the Deep River basin was bordered on the southeast by a highland area, and that the deposits in the basin were derived from the erosion of this highland.

CONDITIONS OF DEPOSITION

The extremely coarse, angular, fresh, and poorly-sorted materials comprising the fanglomerate along the southeastern border of the Deep River basin are typical of alluvial fan deposits at the bases of present fault scarps. These Triassic deposits probably accumulated at the base of a scarp along the southeast (Jonesboro) border fault. It is inferred, therefore, that the Jonesboro fault was active during the late Triassic, and that uplift of the sediment source area southeast of the Deep River basin and subsidence of the basin during deposition were accomplished by movements on this fault. These inferences are supported by certain structural evidences presented in the chapter on structure.

Sediments eroded from the highland southeast of the Deep River basin were carried westward into the basin by streams flowing across the Jonesboro scarp. Coarse sediments were deposited near the scarp, finer sediments were carried farther into the basin. After long periods of quiescence on the fault, the highland was probably topographically subdued and covered with a heavy soil mantle. At these times, the streams had lower gradients and carried fine-grained, dominantly dark-brown or red sediments derived mainly from this soil mantle. Movements on the fault rejuvenated the streams in the highland area and caused them to cut through the soil cover and into the fresh bedrock beneath. At these times, the streams carried the coarser, fresher, and dominantly light-colored materials that comprise the beds of coarse sandstone, conglomerate, and fanglomerate. The correlation of Triassic sedimentation with structural deformation of the Deep River basin is discussed in the chapter on structure.

During most of the period of Triassic sedimentation, the Colon cross structure was the locus of the principal drainage entering the Deep River basin. Coarse sediments were deposited there at the same time that finer sediments, including coal and black shale, were deposited in the Sanford and Durham basins. Toward the close of the period of sedimentation, differential subsidence of the basin may have been accompanied by a shift in drainage—this is indicated by the fact that the coarsest debris in the youngest Triassic sediments is farther east, in the Durham basin.

Irregular bedding, poor sizing, fluviatile crossbedding and channel-like form of some of the coarse-grained sediments indicate that the Pekin and Sanford formations were deposited by streams. Coarse sediments were deposited mainly in channels, and fine sediments were deposited mainly on flood plains. Windfaceted pebbles are present in both formations (as shown on pl. 1), but eolian crossbedding has not been recognized in the mapped area, and the total effect of wind action was probably small. In contrast, the regular bedding, uniform size, relatively fine grain, and abundant fossil content of water-inhabiting vertebrates and invertebrates indicate that most rocks in the Cumnock formation were deposited in lakes. The coal beds are the products of swamps.

Dark-brown or red colors, which are characteristic of the fine sediments and matrices of the coarse sediments in the Pekin and Sanford formations, indicate that these formations were deposited in a non-reducing environment. Most of these sediments probably accumulated on well-drained alluvial piedmont slopes. They were not subject to burial in stagnant, oxygen-deficient waters, which would reduce the red or brown ferric oxide and destroy the color. Sediments deposited in poorly-drained parts of the basin were not extensively de-oxidized, however, because it is probable that the rainfall was seasonal. The ground probably was dry, and the water table remained low for a large part of the year. Oxidation during the dry periods more than compensated for any reduction that may have occurred when the sediments were saturated during the rainy season. Under these conditions the original redness of the sediment was maintained or accentuated, and any organic material in the sediment was oxidized or destroyed by bacteria. Fossils are notably scarce in the Pekin and Sanford formations, except for abundant fragments of petrified wood in the basal Pekin conglomerate. Windfaceting and polishing of pebbles in these formations probably occurred during the dry seasons.

The gray and black colors of rocks in the Cumnock formation indicate that these sediments were deposited in a reducing environment. They accumulated on a moist, poorly-drained basin floor, in swamps, and in lakes. Under these conditions, organic material in the sediments was not oxidized. The carbonaceous matter reduced the original ferric oxides and changed the color of the sediments to gray or black. Some of the ferrous oxide produced by this reduction reacted with water and carbon dioxide to form siderite. The siderite was then precipitated, either as nodules or "iron balls" in some shale beds, or as siderite-rich, carbonaceous blackband.

During the time of the Newark deposition, the climate probably was moist and humid. The environmental significance of the Triassic red beds, which are characteristic of most eastern Triassic basins, has been a subject of great interest and controversy, and much has been written on the problem. The most recent and thorough treatment of the significance of the Triassic red beds is by Krynine (1950, p. 143–154). He regards the Triassic red beds as sediments derived mainly from red soils produced by weathering of the silicate rocks in the source area. He notes that red soils are formed in warm (60° F., or more), humid (45 inches or more annual rainfall) climates,[5] and that red sediments are being deposited and maintained without loss of color on tropical piedmonts receiving seasonal rainfall. He concludes that the Triassic climate in the vicinity of the eastern Triassic basins was warm and humid, with rainfall concentrated into a short rainy season. These conclusions are in general agreement with conditions observed in the Deep River basin.

The existence of swamps and lakes in parts of the Deep River Triassic basin during Cumnock time—as indicated by the coal, gray and black shale, and abundant fossils of the Cumnock formation—does not indicate that the climate then was more humid than it was in Pekin and Sanford time. Instead, it probably indicates that the drainage of the Deep River basin was temporarily ponded because of warping of the basin surface, or because of the growth of fans, deltas, or other nat-

[5] Red subsoils are now forming over the Carboniferous(?) granite and over some of the basic pre-Triassic metamorphic rocks near the Deep River basin, where the temperature averages about 60° F. and the rainfall averages about 45 inches. Gray and yellow soils are quantitatively more abundant in this region at the present time, however.

ural obstacles to the drainage. Sediments deposited in the Cumnock swamps and lakes are lithologically different from the sediments in the Pekin and Sanford formations. Sediments deposited on higher ground in the Colon cross structure during Cumnock time, however, are lithologically similar to sediments in the Pekin and Sanford formations. The Cumnock formation records a period of orogenic inactivity in the Deep River basin, which was long enough for the deposition of nearly 800 feet of swamp and lake sediments—an episode that ended when the swamps and lakes passed out of existence and through-flowing drainage was reestablished.

AGE OF THE SEDIMENTS

The Deep River sediments were classed as partly Permian and partly Triassic by Emmons (1856, p. 277–282); these age determinations were based on vertebrate fossils in the black shale. Redfield (1856, p. 363) subsequently examined the fish remains in Emmons' collection and concluded that they were identical with forms in the northern Triassic basins. In 1883, Fontaine (p. 97–128) reviewed the sketches and descriptions of Deep River plants previously published by Emmons, inasmuch as the location of the Emmons collection was unknown at that time. He listed 39 different species from the North Carolina sedimentary rocks, 15 of which are present also in the Virginia Mesozoic and 9 of which were peculiar to North Carolina and not closely allied with forms from other localities. He found that 8 species were identical, or closely allied, to Jurassic forms of other countries and 15 were identical, or closely allied, to Rhaetic forms of other countries. He concluded that the Virginia and North Carolina Triassic sedimentary rocks are the same age, and that they are not older than latest Triassic.

The status of the plant record from the Deep River rocks was reviewed in 1899 by Ward (1899, p. 266–272, 274–277), and in the same report additional descriptions of plants were given by Knowlton (p. 272–274) and Fontaine (p. 277–315). Descriptions of petrified wood from the basal conglomerate near Lockport were presented in this report by Knowlton, who classed them as Triassic and identical with forms from the Richmond Triassic basin of Virginia. Also in Ward's report are descriptions by Fontaine of plant specimens from the Emmons collection—these specimens were located after Fontaine's earlier report was published.

Since the work of Fontaine and Knowlton, the Deep River sedimentary rocks have generally been listed as Upper Triassic. However, almost all of the plant remains that were studied by these men came from the Cumnock and Pekin formations in the lower part of the section. Therefore, it is possible that the youngest sedimentary rocks in the Deep River basin, which are in the upper part of the Sanford formation and have not yielded diagnostic fossils, may be of Jurassic age.

TRIASSIC IGNEOUS ROCKS

FORM AND DISTRIBUTION OF INTRUSIVES

Igneous rocks of probable Triassic age are widely distributed in eastern North America. In Nova Scotia, New England, New York, and New Jersey, extrusive basalt flows are interbedded with the Triassic sediments, and in all the larger Triassic basins, from Nova Scotia to the Carolinas, the Triassic sedimentary rocks have been intruded by basic igneous rocks (mainly diabase). Diabase dikes are also extensively distributed in the pre-Triassic rocks of the Piedmont plateau and in the pre-Cretaceous rocks beneath the Coastal Plain.

In the Deep River basin there are no basalt flows, but diabase intrusives are present in the form of dikes, sills, and sill-like masses that are only partly controlled by bedding. Diabase dikes cut the pre-Triassic rocks northwest of the Deep River basin, all the Triassic formations within the basin, and the pre-Triassic rocks southeast of the basin (where they pass beneath the cover of post-Triassic sand and gravel deposits along the inner edge of the Coastal Plain). Sills and sill-like intrusive masses are not present in the pre-Triassic rocks, but they are present in all the Triassic formations, and they are thickest and most extensive in the Cumnock formation. Diabase intrusives occupy about 4 percent of the total area of the Deep River Triassic basin; they are considerably less extensive in the pre-Triassic rocks adjoining the basin.

DIKES

Diabase dikes in the Deep River coal field range in width from less than an inch to more than 300 feet, and they range in length from a few feet to almost 7 miles. The widest dike (about 320 feet) is half a mile north of Haw Branch; the longest dike crosses the Sanford Basin 2 miles west of Tramway (see pl. 1). Most dikes in the mapped area are between 20 and 75 feet wide and maintain a fairly constant width for several thousand feet. Dikes in the pre-Triassic rocks are commonly more narrow than those in the Triassic belt; few are more than 30 feet wide.

Most dikes in the Deep River coal field trend N 15° to 40° W. They follow northwest-trending joints and cross faults, along which displacements are generally no more than 50 feet. A change in the trends of the dikes and of the related system of joints and cross faults is apparent near the northeastern end of the Sanford basin. Dikes in the Colon cross structure and in the southern part of the Durham basin trend N 15° to 20° W, whereas those in the Sanford basin trend N 25° to 40° W. Most dikes in the Colon cross structure and in the southeastern part of the Sanford basin (where there are no known longitudinal, northeast-trending faults) are remarkably straight, continuous, and parallel, but in the northwestern part of the Sanford basin (which is traversed by a number of important longitudinal faults) the northwest-trending dikes are shorter, less continuous, and have a less consistent trend. Dikes of this trend are most abundant in the younger Triassic strata along the southeastern side of the Deep River basin; they become progressively less abundant in the older Triassic formations nearer the northwestern side of the basin, and are least abundant in the pre-Triassic rocks. This suggests that the conditions for emplacement of the dikes were progressively more favorable higher in the Triassic sedimentary prism or nearer its southeastern edge.

A few dikes in the Deep River coal field follow northeast-trending longitudinal faults; the largest one follows the Gulf fault from Gulf almost to Carbonton and has been encountered in several mines in that area. Diabase also crops out for short distances along most of the other northeast-trending faults in the Triassic basin, but here the amounts of diabase are remarkably small as compared with the amounts along the northwest-trending cross faults. Except for the Gulf fault, the longitudinal faults were apparently less favorable loci for the emplacement of diabase than were the cross faults. Possible explanations for this distribution are discussed in the chapter dealing with the structural geology of the Deep River field.

Most northwest-trending dikes end a few tens, or a few hundreds, of feet before reaching a northeast-trending longitudinal fault. Where dikes extend to such a fault, they commonly change direction, become irregular in width near the fault, and spread out along the fault for short distances. Where dikes extend across a fault, they usually change direction abruptly at the fault. The fact that a few dikes extend across faults with little break in continuity has no significance in regard to the displacements on the faults, because the diabase was intruded after the main episode of faulting in the Deep River coal field.

Observed dips of dikes in the Deep River coal field range from 25° to 90°. Most dikes are nearly vertical. The westernmost dike in the Cumnock mine, which has been mapped both on the surface and in the mine (see pl. 3), has an average dip of only 25°, and its intersection with the coal is several hundred feet from its position on the surface. It is likely that the dips of other dikes may be so flat, and their downward extent from the surface may be so irregular, that they intersect the coal at considerable distances from their positions on the surface. This should be kept in mind by those planning mining operations in the field. Even dikes that appear vertical at the surface may not continue vertically until they reach the coal.

Most dikes have sharp, fairly straight contacts with the adjacent sedimentary rocks, as shown in figure 21, but in areas of strongly faulted and folded rocks the dike contacts may be very irregular, as shown in figure 22. Wall rocks adjoining the dikes generally show little deformation as a result of the intrusion of the diabase, although along some dikes the strata have been contorted by faulting that occurred prior to the intrusion. Near a few dikes, wall rocks have been tilted upward as much as 15° or 20° from normal position by the intrusion. An example of tilting caused by a dike is shown in the photograph of a cut on the Seaboard Railroad northeast of Colon (see fig. 23). Along most dikes, wall rocks are cut by closely spaced vertical fractures that are perpendicular to the contact and die out away from it.

SILLS AND SILL-LIKE INTRUSIVES

Sills and sill-like intrusives are almost completely confined to the Cumnock formation in the Deep River coal field. Between Gulf and Haw Branch, one-third to one-half of the territory between the top and base of the Cumnock formation is underlain by diabase in sills and sill-like intrusives that are as much as 400 feet thick. Sills in the Cumnock formation crop out southwest of Horse Shoe Bridge (see pl. 1), and thick masses of diabase encountered in this formation in drill holes BDH 2, 3, 6, and 9, may also be sills (see fig. 9). Although similar intrusive masses are not present in the Pekin formation within the mapped area, sills are present in the lower part of the Triassic section at the northern end of the Durham basin. The only exposed sill of any appreciable size (1½ miles long and about 50 feet thick) in the Sanford formation crops out near Euphonia Church in western Lee County.

The sills and sill-like intrusives in the Triassic sedimentary rocks have formed where the diabase magma, moving upward along joints and faults, has spread laterally or obliquely across the beds. This has occurred mainly in the thin-bedded or fissile shale in the upper part of the Cumnock formation. Most intrusives of this type are in areas where the rocks are strongly faulted and folded. Sill-like intrusives between Gulf and Carbonton (which are stratigraphically lowest near Carbonton) are in the zone of faulted, contorted rock near the Gulf fault and are connected with the dike

FIGURE 21.—Diabase dike in Sanford formation 1 mile south of Sanford. Contact of diabase (light) with siltstone (dark) is indicated by hammer. Dike is about 30 feet wide, trends perpendicular to plane of photograph. Exposure on county road 1,300 feet west of Buffalo Church.

FIGURE 22.—Diabase dike in Pekin formation 7 miles northeast of Sanford. Contact of diabase (light) with claystone (dark) is unusually irregular. Note sinuous dike 3 inches wide to the left of the hammer. Exposure on county road one-fourth of a mile north of Rosser.

FIGURE 23.—Diabase dike in Sanford formation 6 miles northeast of Sanford. Beds of conglomerate and sandstone are tilted upward on both sides of dike. Camera faces eastward. Dike trends southeastward, oblique to photograph, and is 4 to 6 feet wide. Beds are downthrown 4 feet on northeast side of dike. Exposure along Seaboard Railroad, 1 mile north of Osgood.

that follows the fault (see fig. 24). Sill-like intrusives between Carbonton and Haw Branch are in the strongly folded rock along the northern side of the Deep River fault.

There is little evidence available in regard to the manner of emplacement of the sills. Rocks near some intrusives appear little disturbed, as though the magma had simply replaced the rock it intruded, but in other places, the rocks are considerably fractured and disarranged. Abnormal increases in thickness of the Cumnock formation in drill holes BDH 3 and 9, and in BMDH DR–2, correspond approximately to the thicknesses of what appear to be sill-like intrusives encountered in these holes. This suggests that the intrusive magma may have lifted the overlying strata to make room for itself.

Unexposed, deeply buried sills may be widespread in the Deep River Triassic basin. Many dikes that appear on the surface may have been fed upward from sills. Some information on the subsurface distribution of intrusives can probably be obtained by geophysical methods, but an accurate determination of the extent of buried intrusives can be obtained only by mining and drilling.

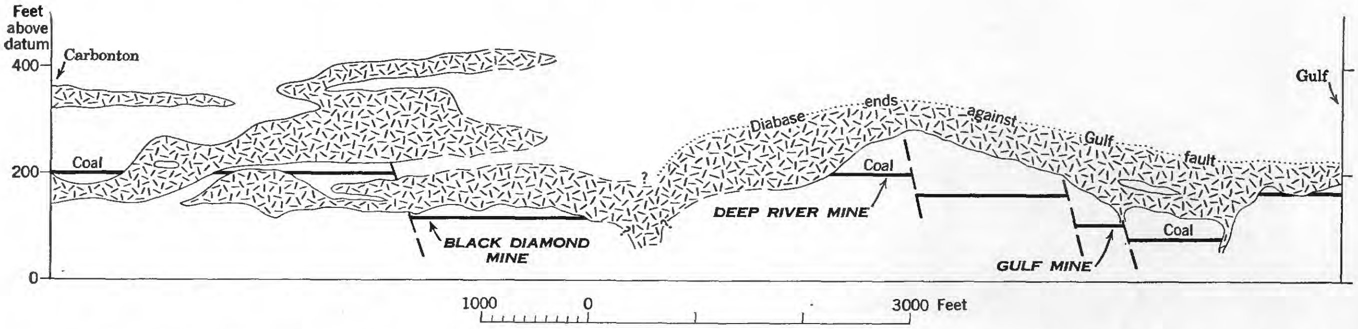


FIGURE 24.—Theoretical longitudinal section showing relationship between sill-like intrusives and coal beds from Carbonton to Gulf, in a plane perpendicular to the bedding.

MINERALOGY AND PETROLOGY

MINERALS

Microscopic examination of 17 thin sections of Triassic intrusive rocks from the Deep River coal field showed that these rocks are composed of the following minerals.

Primary minerals: olivine, plagioclase feldspars (andesine, labradorite, bytownite), augite, potash feldspar (orthoclase), and quartz (both orthoclase and quartz are commonly intergrown, forming micropegmatite).

Accesory minerals: magnetite, ilmenite, pyrite, chromite (?), titanite, apatite, and basaltic hornblende.

Secondary minerals: antigorite, iddingsite, actinolite, sericite, kaolinite, limonite, hornblende, calcite, and magnetite.

Olivine is present in all but one of the thin sections that were examined, and it constitutes more than 50 percent of two of the sections. It is in untwinned, colorless, six-sided euhedral crystals, which usually are partly altered to pale-green antigorite and secondary magnetite. Grains in some sections are so extensively altered that the crystal form is obliterated. In three of the sections, reddish-brown iddingsite is the alteration product. The olivine commonly contains inclusions of magnetite, and small crystals of plagioclase, and olivine grains are included within larger crystals of plagioclase and augite. In a few sections, embayed crystals of early olivine are included within crystals of olivine that were formed later.

Plagioclase feldspars form a third to two-thirds of most Triassic igneous rocks in the Deep River coal field. They are in colorless, lath-shaped crystals ranging from long and slender to short and broad. Most crystals have albite twinning; in a few sections, Carlspad twinning is common, but few of the crystals show pericline twinning. The compositions of the plagioclases range from Ab_{65} An_{35} (andesine) to Ab_{20} An_{80} (bytownite); the composition moves toward anorthite as the olivine content of the rock increases. Zoned plagioclase crystals are rare. Plagioclase crystals are euhedral except in contact with some olivine. They have embayed edges in contact with olivine or augite in some sections. Generally, the plagioclase crystals are randomly oriented or form star-like clusters. In one section, they are in mosaic aggregates separated by large areas containing little plagioclase. Plagioclase in some thin sections is altered along cracks or in rounded patches to sericitic material; in one section it is extensively kaolinized.

Augite forms as much as a third of the Triassic igneous rocks in the Deep River field; the quantity of augite present in these rocks is, in general, inversely proportional to the quantity of olivine. Augite commonly is in colorless or faintly brownish, irregular plate-like crystals of variable size and shape that fill the interstices between plagioclase and olivine crystals. In one section, the augite is in lath-shaped, twinned crystals that are in parallel orientation with adjacent plagioclase crystals and are of approximately the same age. The augite is generally less altered than olivine and plagioclase, but it is partly changed to secondary actinolite in some thin sections, and it is changed to secondary hornblende in one section. Augite and actinolite are commonly changed to chlorite in weathered diabase. Calcite patches, apparently derived from augite, were observed in one specimen.

A few discrete grains of orthoclase and quartz are present in some specimens, but usually these minerals form an intricate intergrowth known as micropegmatite, which fills small interstices between the other minerals. Micropegmatite forms no more than 12 or 13 percent of the rock, and it becomes less abundant as the proportion of olivine in the rock increases. It commonly contains inclusions of the accessory minerals.

The accessory minerals form no more than three or four percent of the Triassic igneous rocks in the Deep River field. Magnetite is very abundant, and it forms black skeleton or solid crystals (commonly octahedra) in all the thin sections that were examined. It is partly in crystals scattered randomly through the rock and partly in grains along cracks and edges of olivine crystals, where it has probably been formed by alteration of the olivine. In weathered rocks, magnetite is commonly altered to limonite. Ilmenite is probably almost as abundant as magnetite, but it was not distinguished from magnetite except where its white alteration product, leucoxene, was present. Black, unaltered magnetite is intergrown with leucoxenized ilmenite in one thin section. The other accessory minerals are present only as a few scattered grains in some of the rocks.

TEXTURES AND FACIES

All the Triassic igneous rocks of the Deep River coal field are crystalline; no glassy phases have been observed. The largest crystals observed are 3½ mm long. Crystals of olivine, plagioclase, and augite, near the center of large sills and dikes, are typically from 2 to 3 mm across, and near the edges of intrusives they are commonly less than ½ mm across.

The primary minerals are present in different proportions in the intrusives of the Deep River field, and changes in the proportions of the minerals are accompanied by changes in the fabric of the rock. Three facies, differing in mineral proportions and in fabric, are exhibited by the specimens that have been examined.

1. *Gabbroic diabase.*—More than one-half of the rock

is composed of olivine. Plagioclase forms about one-third of the rock, filling interstices between olivine crystals. Augite forms less than one-tenth of the rock and micropegmatite is absent.

2. *Normal diabase.*—More than one-half of the rock is composed of plagioclase. Augite forms one-eighth to one-fourth of the rock, filling interstices between the plagioclase. This is the ophitic fabric typical of most diabase. Olivine generally forms less than one-fifth of the rock, and several percent of micropegmatite is present.

3. *Dioritic diabase.*—About one-half of the rock is composed of plagioclase. Augite forms about one-third of the rock and is intergrown or in parallel growth with plagioclase (the two are about the same age). Micropegmatite forms more than one-tenth of the rock, and olivine is absent.

Proportions of minerals in 10 thin sections of Triassic igneous rocks were determined by the Rosiwal method. Table 7 shows the contents of primary and accessory minerals in these specimens and shows the relationship between mineral composition and rock facies. Specimens D–3 to D–9 possess a fabric that is esentially ophitic, although there is a considerable range of compositions among them. Further investigation would probably reveal the existence of rocks having mineral compositions intermediate between specimens D–2 and D–3.

Locations of the specimens listed in table 7 are shown on the structure map, plate 4. Specimens D–1 and D–2 are from the same dike. This is the only dike that has an observed olivine content exceeding 25 percent, but there probably are other high-olivine dikes in the Deep River coal field. Specimen D–10 came from a dike east of Corinth (the only one that contained no olivine). All the specimens are from the centers of the dikes. No important mineralogical differences between rocks from centers and from margins of these intrusives have been observed.

TABLE 7.—*Percentage distribution of minerals in Triassic igneous rocks of the Deep River coal field*

Minerals	Facies									
	Gabbroic diabase		Normal diabase							Dioritic diabase
	D–1	D–2	D–3	D–4	D–5	D–6	D–7	D–8	D–9	D–10
Olivine	59	58	20	18	18	13	13	10	Tr.	-----
Plagioclase	37	31	55	55	53	59	61	64	65	48
Augite	3	8	21	22	16	25	16	20	26	37
Micropegmatite	-----	-----	-----	3	10	2	7	4	7	13
Magnetite-ilmenite	1	3	4	2	3	1	3	2	2	2
Pyrite	-----	Tr.	-----	-----	-----	-----	-----	-----	-----	-----
Chromite (?)	Tr.	-----	-----	-----	-----	-----	Tr.	-----	-----	-----
Titanite	-----	-----	-----	-----	Tr.	Tr.	-----	-----	-----	-----
Apatite	Tr.	-----	-----	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Basaltic hornblende	-----	-----	-----	-----	-----	Tr.	Tr.	-----	Tr.	-----

Intrusive igneous rocks of the Deep River basin and of the other Triassic basins in Eastern United States are generally listed as diabase, and they are dominantly diabasic in texture and in composition. The gabbroic and dioritic diabase facies present in the Deep River coal field, however, are not strictly diabase in either texture or composition. Similarly, the so-called diabase of other eastern Triassic areas exhibit many non-diabasic facies. For example, Lewis (Stose and Lewis, 1916, p. 634–637) recognized nine varieties in the Triassic igneous rocks near Gettysburg, Pa., ranging from basalt and diabase (containing abundant olivine) to aplite (containing abundant quartz and orthoclase). Tomlinson (1945) summarized the mineral compositions of diabases from Virginia to New Jersey, and found five main facies, ranging from normal diabase containing 42 percent augite, 46 percent labradorite, and no quartz, to aplitic diabase containing 57½ percent albite, 24½ percent quartz, and no augite or labradorite.

Diabases of the Deep River coal field are higher in olivine content than most Triassic igneous rocks of Eastern United States. The "normal diabase" of the Deep River field has an average olivine content of more than 10 percent (this is about the same percentage content as the "olivine diabase" described by Lewis). Olivine is not a constituent of the five principal facies described by Tomlinson. On the other hand, the quartz-rich and albite-rich facies of other Triassic areas have not been observed in the Deep River region.

COLOR

The color of fresh "normal diabase" is usually grayish black (N2), "gabbroic diabase" is dark gray (N3) or medium dark gray (N4), and "dioritic diabase" is olive black (5Y2/1). Rocks in which olivine has been partly altered to iddingsite or antigorite have red or green pigment added to the above colors. Weathering introduces brown pigment from limonite, subordinate amounts of white pigment from kaolin and green pigment from chlorite.

TOPOGRAPHY AND WEATHERING

Although dikes and sills usually form topographically inconspicuous low ridges and divides, they have an important influence on the drainage patterns of the Deep River region. The courses of such streams as Crawley, Little, and Killets Creeks near Carthage, of Buffalo, Pattersons, and Pocket Creeks near Sanford, and of the tributaries of Hughes and Lick Creeks, east of Colon, are determined to a large extent by the trends of the dikes. Many of the abrupt bends in Deep River (particularly near Gulf), and many peculiarities in the courses of tributaries of Deep River, are where the streams encounter dikes or sills. Because the diabase is more resistant to erosion than most of the Triassic sedimentary rocks, rapids usually are present where the streams cross dikes. Where heavily alluviated streams (such as McLendons Creek and Lick Creek) cross dikes, the alluvial fills are thinner and narrower.

Many streams originate in springs produced by movement of ground water along margins of intrusives. Some of these springs are shown in plate 1. They insure a fairly steady flow of water in many streams in the region, and they are important sources of water for domestic use. Local inhabitants have learned by experience that dikes are favorable locations for water wells.

The Triassic intrusives are usually marked by a surface accumulation of diabase boulders, which are products of spheroidal weathering facilitated by the jointing of the rock. Where runoff is rapid—with the result that the rock surfaces do not long remain wet, and the products of rock decay are quickly removed—these boulders may be relatively hard and fresh throughout, and there may be very little soil around them. Where drainage is slower, the boulders commonly have a number of concentric rings from one-fourth to three-fourths of an inch thick in which the fresh rock is in successive stages of decomposition, and they are immersed in an accumulation of red or brown material resulting from the decomposition of the diabase. Under such conditions, diabase boulders, as much as several feet in diameter, may contain no more than a few inches of fresh diabase at the center. The remainder of the rock consists mainly of white kaolin grains (resulting from the decomposition of plagioclase) embedded in brown linonitic clay (resulting from the decomposition of olivine and augite).

Two types of soils develop from the Triassic intrusive rocks. One type consists of a brown or grayish-brown silty loam surface soil and a brown to yellow, sticky, waxy, impervious clay subsoil containing abundant slightly-weathered diabase fragments. Fabric and flow lines of the original rock commonly are preserved in the subsoil, and boulders of nearly fresh diabase commonly are present in the soil and on the surface. The following percentage analysis of this material was made by Chatard (Clark, 1887, p. 138): SiO_2, 39.55; Al_2O_3, 28.76; Fe_2O_3, 16.80; CaO, .37; MgO, .59; MnO, trace; Cr_2O_3, trace; P_2O_5, .10; TiO_2, .64; alkali, undetermined; and H_2O, 13.26.

The other soil developed from diabase consists of a dark-red to brownish-red heavy clay loam surface soil and a dark-red, heavy, stiff or friable, clay subsoil. No relic flow structures exist and few boulders or fragments that retain diabase fabric are present in the soil; those present are severely weathered. This soil represents a more thorough oxidation and a more complete decomposition of the diabasic material than does the brown soil.

Diabase intrusives can readily be traced by their effects on topography and drainage, by the surface accumulations of boulders, and by their distinctive soils. Additional aides are the cedar trees, which prefer the diabase soils, and the baked and blackened zones of metamorphosed sedimentary rocks along the intrusive contacts. Many of the topographic, vegetative, and color effects of the Triassic intrusives can be recognized on aerial photographs.

METAMORPHIC EFFECTS

Contact metamorphic effects produced in Triassic sedimentary rocks by diabase intrusives generally extend less than 30 feet from the intrusives. Claystone rarely shows any effects at distances greater than 10 feet regardless of the thickness of the intrusive, but siltstone, sandstone, and conglomerate are commonly affected as far as 30 feet from an intrusive contact. In the coarser-grained sediments the width of the metamorphosed zone is more directly related to the size of the intrusive. Even the thickest sill-like masses near Carbonton have had little effect on rocks farther than 30 feet above or below the intrusive, except in a few places where the wall rocks are strongly brecciated.

Metamorphism of the sedimentary rocks has produced magnetite by oxidation of the iron oxides, has caused the recrystallization of quartz, and has resulted in the development of sericite and feldspar from kaolin and clay minerals. In claystone, the principal metamorphic effect is the blackening of the rock caused by the development of magnetite. Shale and siltstone have generally become much harder as the result of recrystallization of the quartz during metamorphism, thus yielding a rock that resembles the spotted hornfels, described by Stose and Jonas (1939, p. 131), from the Triassic of Pennsylvania. Dark spots, commonly ring-shaped, consist of magnetite dust; light spots consist of irregular quartz grains, mosaic quartz aggregates, and feldspar crystals in various stages of development. The groundmass consists mainly of kaolin and quartz, and scattered iron oxide grains. Sandstone has been similarly darkened and hardened by intrusions, although the coherency of some coarse-grained gray sandstone, composed largely of schist fragments, has been decreased by metamorphism. Bleaching of sandstone, which has been reported in many Triassic areas, has not occurred extensively in the Deep River basin.

Diabase intrusives have had a profound effect on the coals in the Deep River coal field. Dikes that cut through coal beds have converted the coal to coke in zones several feet wide on both sides of the intrusives. Sills that are near the coal beds have thinned the coal and have converted it to anthracite over extensive areas in the vicinity of Carbonton; locally, the sills have destroyed the coal. These changes are of great importance to mine operators, not only because the market for coke and anthracite differs from that for the unmetamorphosed coal, but also because mining conditions are generally poorer where metamorphism has occurred. The conditions under which coal is altered to coke or anthracite, and the extent to which this alteration has occurred in the Deep River coal field, are discussed more fully in the chapter on coal.

AGE OF THE INTRUSIVE ROCKS

The diabase igneous rocks of the Deep River coal field intrude the youngest Triassic sedimentary rocks. They are older and pass beneath the sand and gravel deposits along the southeastern side of the Triassic basin, which may be late Tertiary or possibly Cretaceous; they do not intrude Cretaceous and younger rocks farther east in the Coastal Plain. In the Deep River region the evidence suggests only that the intrusive rocks may be as old as late Triassic, or as young as early Cretaceous.

The age of the diabase intrusive rocks in other eastern Triassic basins and in the Piedmont plateau has generally been regarded as Triassic. Darton (1890, p. 70–71) and Davis (1898, p. 79–80) considered the extrusive flows and intrusive sheets of the New Jersey and Connecticut Valley areas to be associated with faulting that occurred during, and following, the Triassic sedimentation. Roberts (1928, p. 62) suggested that the diabase intrusions in Virginia occurred partly during, but mostly following, the sedimentation in the late Triassic. Stose and Jonas (1939, p. 166) believe that the intrusions in the Triassic of southern Pennsylvania accompanied the faulting and sinking of the basin at the close of the Triassic.

In the Deep River coal field there is no evidence that volcanic activity occurred during the Triassic sedimentation or before most of the faulting and tilting of the basin had been completed. The intrusive rocks follow pre-existing structures and are rarely offset more than a few feet by later faults. Probably, they formed in the final stages of faulting near the end of the Triassic, but they may be younger.

POST-TRIASSIC ROCKS

GENERAL DESCRIPTION

Post-Triassic formations in the Deep River coal field include high-level surficial sand and gravel deposits along the southeast side of the Triassic trough, terrace gravel deposits along the Deep, Haw, and Cape Fear Rivers, colluvium or slope-wash deposits in the vicinity of Carthage, and alluvium or flood plain deposits along the streams. All these deposits are unconsolidated. Because of their lithologic character and their physiographic position, the high-level sand and gravel have generally been regarded as Tertiary, possibly Pliocene, in age. The age of the deposits cannot be determined with certainty because no fossils have been found and the deposits have not been traced into formations of known age. The river terrace deposits are probably Pleistocene, and the colluvium and alluvium are Pleistocene and Recent.

HIGH-LEVEL SURFICIAL DEPOSITS

DISTRIBUTION AND THICKNESS

High-level surficial sand and gravel deposits of possible Pliocene age are distributed along the southeastern side of the Deep River coal field and cover almost a fifth of the area shown on the geologic map (pl. 1). These deposits are part of a northeast-trending belt, 5 to 30 miles wide, of surficial sand and gravel that lies along the inner edge of the Coastal Plain, extends discontinuously across the center of North Carolina, and converges toward the southwest with the belt of Triassic rocks that includes the Deep River and Wadesboro Triassic basins. Northeast of the Cape Fear River the belt of surficial deposits is generally east of the Triassic belt, but southwest of the Cape Fear River these deposits gradually overlap and progressively conceal the Triassic rocks along the southeast side of the Sanford basin. A few miles southwest of the mapped area (northwest of Pinehurst) the deposits of high-level sand and gravel extend completely across the Triassic and cover the pre-Triassic rocks on the northwestern side of the Triassic belt.

Near the Deep River coal field these surficial deposits rest unconformably on Triassic sedimentary and igneous rocks and on pre-Triassic igneous and metamorphic rocks. At Carthage, they extend about 3 miles beyond the southeastern edge of the Triassic basin. Southeast of the area shown on plate 1, they rest mainly on Cretaceous sedimentary rocks of the Coastal Plain.

The post-Triassic high-level sand and gravel filled the valleys and covered the hills of the uneven surface that had been eroded on the pre-Triassic, Triassic, and Cretaceous rocks of the region. The configuration of this surface probably resembled the present landscape; erosion has subsequently removed these deposits from most of the valleys, leaving a mantle mainly on hills and on higher valley slopes. Patches of this sand and gravel still remain, however, in the valley of McLendons Creek; here, these patches are 300 feet above sea level,

FIGURE 25.—Post-Triassic deposits overlying pre-Triassic rocks 2 miles south of Sanford. Post-Triassic deposits (light) are unconsolidated arkosic sands; pre-Triassic rocks (dark) are weathered schist. Irregular contact is offset several inches by a fault in center of cut. Exposure on Seaboard Railroad near State Highway 78.

but almost 150 feet below the base of the formation at Carthage, 6 miles to the east. The irregularity of the surface underlying the post-Triassic high-level sand and gravel deposits is well displayed in a railroad cut 2 miles south of Sanford (shown on fig. 25) where these deposits overlie eroded pre-Triassic metamorphic rocks. Usually the stratification in the lower part of these deposits reflects the configuration of the surface on which they rest. This is well shown in a road cut 7 miles southwest of Carthage (see fig. 26).

The area occupied by this formation is very irregular. Its northwestern limit is notched and serrated by streams flowing northward into the Triassic trough. The concerted erosive attack of these streams is causing a steady southeastward retreat of the contact and of the north-facing escarpment that the capping of sand and gravel helps to maintain (see pl. 2, section B-B′). Farther northwest are small patches of the formation that have been isolated by erosion; one of these covers the surface of a hill in the Triassic basin 3 miles north of Carthage. The southeastern limit of these high-level sand and gravel deposits in the mapped area is an intricately dissected contact produced by southward-flowing streams, which have cut through these deposits and have exposed the Triassic and pre-Triassic rocks underneath.

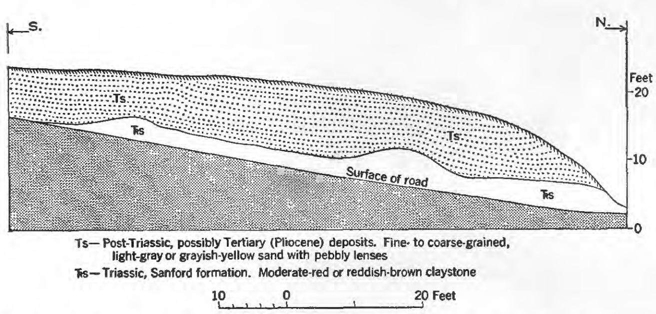


FIGURE 26.—Sketch showing relationship of post-Triassic (Pliocene?) deposits to underlying Triassic rocks in road cut 7 miles southwest of Carthage.

In the vicinity of the Deep River coal field the high-level sand and gravel deposits are generally not more than 40 feet thick. They are thickest (130 feet) at Carthage, where the base of the deposits is about 450 feet above sea level, and where the surface has an altitude of about 580 feet.

NOMENCLATURE AND PREVIOUS DESCRIPTIONS

The belt of high-level gravel in northern North Carolina and its continuation in Virginia was studied in 1888 by McGee (1888), who applied the name "Appomattox" to the formation. A more complete description of these deposits in North Carolina was given by McGee (1890) in 1890. The name "Lafayette" was adopted for the formation in 1891 to replace various names, including "Lagrange," "Orange," and "Appomattox," which had been applied to similar deposits from Texas to Pennsylvania, and in the same year, McGee (1891) made the first comprehensive study of the Lafayette formation in the Atlantic and Gulf Coast states. In 1893, Holmes (1893) described the Lafayette and overlying Columbia formations in the sand-hill region south of the Deep River coal field.

Stephenson (1912) made the latest comprehensive survey of the so-called Lafayette formation in North Carolina in 1912. The name "Lafayette" was subsequently discarded, however, after Berry (1911) showed that the deposits of the type locality in Lafayette County, Miss., could not be correlated with the high-level deposits of the Atlantic coast. In 1950, Richards (1950, p. 35–36) briefly described the deposits, referring to them simply as "High-level gravels." Because of the poor exposures and the small area over which this formation has been observed during the present investigation, no attempt has been made to further define or name it.

LITHOLOGIC CHARACTER OF THE DEPOSITS

The general character of the high-level sands and gravels of North Carolina has been described by Stephenson (1912, p. 261–262) as follows:

> The materials of the formation consist of sandy loams, sandy clays, sands and gravels. The coarser phases predominate. In places the sands are arkosic, the included kaolin grains having been derived in part from underlying Patuxent[6] beds and in part from underlying or adjacent crystalline rocks. Sorting has not been thoroughly accomplished except locally, the sands and gravels as a rule containing a more or less regularly disseminated clay content. At some places a large percentage of the pebbles and cobbles in the gravel beds are smoothly rounded, and this is especially true wherever there are considerable accumulations of gravel. Where very thin coverings of the deposits occur, however, resting directly upon the crystalline rocks a considerable percentage of angular or slightly worn quartz is, as a rule, intermixed with the well-worn material.

In the vicinity of the Deep River coal field this formation consists mainly of sandy clay, silt, and sand. Most of the area it occupies is covered by a loose residual mantle of very light-gray or yellowish-gray sandy loam or sand (see pl. 1). Coherent strata are exposed in only a few places. Along U. S. Highway 15, west of White Hill, lenticular beds of sandy clay and argillaceous sand crop out for short distances in several road cuts. The clay strata are various shades of yellow, brown, or orange; the sand is fine- to coarse-grained, light-gray or yellowish-gray. West and south of Carthage, gray and brown coarse-grained arkosic sands interbedded with mottled red and gray clays are exposed in road cuts.

[6] The lowest Cretaceous formation in this region is now believed to be mostly of Late Cretaceous age and is correlated with the Tuscaloosa formation of the southeastern states. (See Stephenson and others, 1942.)

Gravel of two types occurs in the post-Triassic high-level deposits along the southeast side of the Deep River coal field. Southwest of Sanford, there are patches of gravel and sandy gravel characterized by the predominance of white or gray quartz pebbles and cobbles (see pl. 1). Northeast of Sanford, there are patches of gravel, sandy gravel, and pebbly sand characterized by brown, purple, or gray quartzite pebbles and cobbles.

The largest mass of white quartz gravel is a winding channel-like deposit that passes through the town of Carthage and extends from 3 miles east to 2½ miles south of the town. This deposit consists mostly of subrounded to well-rounded quartz pebbles and cobbles, as much as 8 inches across, in a matrix of orange, or brown, arkosic coarse-grained sand. Scattered pebbles of metamorphic rocks are also present in the deposit. The pebbles and cobbles are commonly in irregular lenses typical of stream channel deposition. Figure 27 shows an exposure of this deposit in a road cut on U. S. Highway 15, 2 miles east of Carthage.

Extensive deposits of white quartz gravel and sandy gravel, as much as 10 or 15 feet thick, are at the base of the post-Triassic deposits between White Hill and Tramway. Similar, but smaller, deposits are present near the southwestern end of the mapped area. The quartz pebbles and cobbles in this gravel are more angular than those in the deposit at Carthage, and the proportion of the metamorphic rock fragments is higher. This gravel is apparently a residual accumulation from the underlying Triassic and pre-Triassic rocks which has been incorporated in the post-Triassic deposits.

The gravelly patches northeast of Sanford are distinctively different from anything in the high-level surficial deposits farther southwest. Most of the pebbles and cobbles are of grayish-red purple to purplish-gray quartzite that weathers pale brown or grayish-brown; some are composed of angular clear quartz fragments in a hematitic clay matrix, and a small proportion are of white quartz. Most of the pebbles and cobbles are well rounded, and most of them show percussion marks. The matrix of the deposit consists of coarse, angular to subrounded, clear quartz grains embedded in a brown, orange, or pink limonitic clay. Small fragments of pre-Triassic rocks and bits of carbonized wood have been observed in the matrix. Gravelly materials of this type form most of the high-level deposits in the northeastern part of the mapped area, and they are usually no more than a few feet thick. Scattered quartzite cobbles on ridges near the Cape Fear River are residual from the once thicker and more extensive gravels that have been eroded.

FIGURE 27.—Post-Triassic deposits 2 miles east of Carthage. Part of gravel deposit that extends west to Carthage. Pebbles are mostly white or gray quartz; matrix is coarse-grained, reddish brown arkosic sand. Exposure along U. S. Highway 15.

CONDITIONS OF DEPOSITION

McGee (1891, p. 508) regarded the post-Triassic belt of sand and gravel as a record of marine inundation of the continental margin. He thought that the deposits accumulated near the edge of the invading sea, and that they consist of sediments carried to the sea by streams, spread and reworked by waves and currents along the sea shore, and mixed with materials from the newly formed sea bottom. He believed that the streams had about the same courses before this marine invasion as they do now, and that the present rivers were the chief contributors of the sediments in these deposits. Clark (1912, p. 28) regarded this belt as the highest and oldest of the marine terraces on the Atlantic coast, and he claimed that it differed from the lower terraces of Pleistocene age only in the extent to which it has been eroded.

Some of the materials in the lower part of the high-level deposits near the Deep River coal field probably represent residual accumulations derived locally from underlying rocks. Coarser phases of the formation commonly exhibit characteristics of stream deposits, but some of the finer materials might be littoral deposits. Gravel in the northeastern part of the mapped area apparently came from a source different from that in the southwestern part of the area. The gravel in the northwestern part may have been contributed by the ancestral Haw-Cape Fear River system, whereas the gravel in the southwestern part may have been brought in by some other river—possibly an ancestral Deep River which may have flowed directly into the sea without turning eastward to join the Cape Fear River as it now does. A more precise statement of the conditions under which these deposits accumulated cannot be made until this formation has been studied in detail over a larger area.

AGE OF THE DEPOSITS

The age of the high-level surficial deposits along the southeastern side of the Deep River coal field is a matter of considerable importance. These are the oldest deposits in this area that rest upon the Triassic rocks, and therefore they might be useful in dating the faulting and the intrusions of the Triassic basin. Furthermore, they rest on an erosion surface that has a configuration similar to the present landscape, and they might be of use in determining the physiographic history of the Deep River region.

Within the mapped area, the evidence indicates only that the deposits are post-Triassic. Observations made a few miles east of the Deep River field, by Stephenson, indicate that some of the materials are post-Cretaceous, and the deposits as a whole have generally been regarded as Tertiary, possibly Pliocene. It is possible, however, that these deposits include materials as old as Cretaceous and as young as Pleistocene. By mapping them in detail on a topographic base, and by tracing them laterally into areas underlain by Coastal Plain deposits of known age, it may be possible to determine the age of these post-Triassic high-level surficial deposits.

TERRACE GRAVEL DEPOSITS

DISTRIBUTION AND THICKNESS

Terrace deposits of clay, sand, and gravel are present along the Deep, Haw, and Cape Fear Rivers and along some of their larger tributaries. Where the rivers flow through the Triassic trough from Glendon to Woodard Bridge and from Moncure to Buckhorn Dam, these deposits are as much as 50 feet thick and a mile wide, but where the rivers flow through pre-Triassic rocks west of Glendon, from Woodard Bridge to Moncure, and south of Buckhorn Dam, the terrace deposits are only in very thin, narrow, discontinuous patches. The extensive terrace deposits within the meander bends of Deep River between Glendon and the Carolina mine cover much of the coal outcrop and conceal many structures and intrusives that probably affect the coal.

Within the area covered by the geologic map (pl. 1) the terrace deposits underlie four terrace levels. For purposes of description these terrace levels are designated "Terrace No. 1," "Terrace No. 2," "Terrace No. 3," and "Terrace No. 4," in order of increasing height above the river. The altitudes of these four terraces and their relation to the river profile are shown on figure 4.

Deposits underlying Terrace No. 1 are shown on the geologic map by the symbol Qg_1. This terrace is present only along the lower Deep and Haw Rivers below Moncure, and along the upper Cape Fear River; it is not present farther upstream along the Deep and Haw Rivers. It consists mainly of flat, poorly-drained, channel-like strips separating patches of the higher terraces, and it is commonly utilized by tributaries of the river. The level of this terrace is generally from 20 to 25 feet above the river (170 to 185 feet above sea level).

Terrace No. 2 extends discontinuously from Buckhorn Dam up the Deep River almost to High Falls. Deposits underlying this terrace are shown on the geologic map by the symbol Qg_2. Between Buckhorn Dam and Moncure, the level of this terrace is generally 35 to 45 feet above the river (185 to 205 feet above sea level). From Woodard Bridge to Carbonton, this terrace is generally 20 to 25 feet above the river (225 to 235 feet above sea level). Above Carbonton, it is less than 15 feet above the river, and upstream it gradually approaches river level. Below High Falls, it is almost 260 feet above sea level. Most patches of Terrace No. 2 are narrow, flat, and poorly drained. During floods, patches of this terrace between Woodard Bridge and Glendon are covered by water.

Deposits underlying Terrace No. 3 are shown on the geologic map by the symbol Qg_3. This terrace is present between Moncure and Buckhorn Dam, where it is 75 to 85 above the river (230 to 245 feet above sea level), and from Woodard Bridge to Glendon, where it is 50 to 70 feet above the river (265 to 285 feet above sea level). It is not present where the river flows through pre-Triassic rocks above Glendon, nor is it present from Woodard Bridge to Moncure. Remnants of Terrace No. 3, particularly between Carbonton and the Carolina mine and along the Cape Fear River, are typically broad, flat or gently rolling, deeply dissected near the margins, and topographically prominent because they stand higher than the surrounding country. Deposits of this terrace probably once covered considerable areas from which they have been eroded. The topography of Terrace No. 3 and its relationship to Terrace No. 2 near Cumnock are shown on plate 3.

Patches of terrace gravel at altitudes of 300 feet or more, from Carbonton to Glendon, may be remnants of a still higher terrace, called "Terrace No. 4." The largest remnant of this terrace is east of Glendon at an altitude of about 330 feet. Small patches of terrace material southeast of Gulf and north of the Carolina mine at altitudes between 290 and 310 feet may also be remnants of this terrace. The apparent profile of Terrace No. 4 is shown on figure 4, but the relationship between this terrace and Terrace No. 3 cannot be clearly defined without a topographic map of the region, and therefore the deposits underlying these two terraces are not differentiated on the geologic map (pl. 1). It is possible that some deposits that appear to be remnants of Terrace No. 4 are really outliers of the post-Triassic high-level surficial deposits.

LITHOLOGIC CHARACTERISTICS OF THE DEPOSITS

Terrace deposits underlying Terrace No. 3 and Terrace No. 4 (Qg_3) consist dominantly of friable silty or sandy clay and subordinate amounts of sand and gravel in irregular patches or thin lenses. A surface soil, as much as 15 inches thick, of light-gray to pale yellowish-brown sandy loam usually overlies the less-eroded parts of these deposits. This surface soil is underlain by several feet of friable, moderate- or light-brown, sandy clay, clay loam, or clay, mottled with patches of very light-gray, yellowish-gray, or grayish-orange clay, which is moderately red or red brown at depth. Sand

and gravel lenses constitute only a small part of the deposits, but residual accumulations of sandy gravel are commonly present where the terrace materials have been extensively eroded. Most pebbles and cobbles in these deposits are of white or gray quartz, but pebbles of pre-Triassic metamorphic rocks have been noted, as well as scattered pebbles of Triassic rocks. Most pebbles and cobbles are subangular to subrounded and are less than 4 inches in maximum diameter, but a few boulders as large as 2 or 3 feet across have been observed.

Deposits underlying Terrace No. 3 near the Cape Fear River have a considerably higher content of sand and are more regularly bedded than those farther upstream along the Deep River. The following section of terrace deposits, measured in a railroad cut at Brickhaven, shows the general character of these deposits.

Section of deposits below Terrace No. 3 in cut on Norfolk Southern Railroad at Brickhaven

	Feet	Inches
Loam, sandy, dark-gray (surface soil)	1	
Sand, fine-grained, moderate to dark reddish-brown	5	
Sand, medium-grained, mottled red, brown, and gray in small patches; scattered subangular to subrounded quartz pebbles less than an inch across	2	
Conglomerate, subangular to subrounded, white quartz pebbles, mostly from 1 to 2 inches across, in coarse sand matrix		2
Sand, coarse-grained, in dark reddish-brown, moderate-brown and light-gray patches	4	
Sand, coarse-grained, in light-brown and light-gray patches averaging 6 inches across; scattered quartz pebbles	4+	

Deposits underlying Terrace No. 2 (Qg_2) are generally similar to those under the higher terraces, but the surfaces of these terraces (especially from Glendon to Woodard Bridge) are covered by brown or gray silt and clay from recent floods and by material washed down from higher terraces. The surface soils are usually darker, and here, the reddish patches are nearer the surface than in the deposits underlying Terrace No. 3; however, the over-all composition of the two deposits is about the same.

CONDITIONS OF DEPOSITION

The river terrace deposits of the Deep River coal field are a result of changes in the sediment-carrying capacity of the streams, which caused the rivers and their tributaries to fill (with sediments) the valleys they had previously excavated. At the start of the period of terrace development, the levels of the streams were probably at least 50 feet higher than at present. A succession of four episodes of stream aggradation and valley filling followed; these episodes were separated by periods of downcutting and removal by the streams of part of the previously deposited fill. Each succeeding period of downcutting lowered the valley profiles closer to their present level, and each succeeding episode of alluviation filled the valleys to a level that was lower than that of the preceding fill. The four terrace levels indicate the approximate levels of the four valley fills, and the terrace deposits are remnants of those fills. The episodes of sedimentation and terrace development may have been induced partly by climatic changes, which modified the flow of the streams and altered the supply of sediment they carried, but the upstream convergence of the terraces with the stream level (shown on fig. 4) suggests that these terrace deposits are mainly a result of adjustments of stream gradients to fluctuations in sea level.

All of the terrace deposits along the Deep River above Moncure are typical stream deposits. Some of the materials below Terrace No. 3 (near Brickhaven) are more regularly bedded and better sorted than deposits farther upstream and may be estuarine deposits in part. The materials comprising the Terrace No. 1 deposits along the Cape Fear River, which are very uniform in composition, may also be of estuarine origin.

Deposits beneath Terrace No. 1 (Qg_1), which are present only below Moncure, differ considerably from those of Terrace No. 2 and the higher terraces. They consist of light-gray to light-brown, silty loam surface soil underlain by light-gray, yellow or brown, tough plastic clay. The terrace surface is commonly covered with a thin coat of fine white sand, except near the river, where it is covered with silt and clay from recent floods.

AGE OF THE DEPOSITS

Terraces and terrace deposits along the Deep, Haw, and Cape Fear Rivers are similar to terraces and terrace deposits along most other major rivers of the Atlantic coast. The age of these deposits has generally been regarded as Pleistocene. Fluctuations of sea level that accompanied Pleistocene glaciation are thought to have been the causes of the terrace development, and the terraces are believed to be related to Pleistocene marine terraces of the Coastal Plain.

It is probable that the terrace deposits of the Deep River coal field are mostly of Pleistocene age. Recent alluvium caps parts of Terrace No. 2 and Terrace No. 1, and it is possible that some patches of material mapped as Terrace No. 4, above an elevation of 300 feet, are outlying remnants of the high-level sand and gravel deposits of possible Pliocene age or older (these remnants have already been described). The genesis of the river terraces and their relationships to the Coastal Plain marine terraces are discussed further in the section on geomorphology.

COLLUVIUM

Accumulations of rock detritus classed as colluvium (resulting from slope wash and from soil creep) are present in a few places in the Deep River coal field—

particularly along the borders of the Triassic trough where the slopes are steep. The only colluvium that is extensive enough to be differentiated on the geologic map (pl. 1) occupies an area from 1 to 2 miles northeast of Carthage. This material rests on steep north-facing slopes of an irregular escarpment that is capped by post-Triassic high-level sand and gravel. It consists of light-gray sand and scattered quartz pebbles (materials which have washed down the slopes from the post-Triassic deposits above and which now partially mantle the divides and fill the gullies of these slopes). At the present time, these deposits are being removed by erosion faster than new material is added.

ALLUVIUM

Alluvium is present along most of the streams in the Triassic basin. The most extensive deposits are along the Cape Fear River and along the larger creeks—such as McLendons Creek, Cedar Creek, and Lick Creek. Streams northwest of the Triassic belt have steeper gradients, narrower valleys, and consequently very little alluvium. Most of the streams southeast of the Triassic belt are heavily alluviated with debris from the post-Triassic sand and gravel deposits.

Areas of alluvium shown on plate 1 are covered by Recent stream deposits (mostly by dark-brown or dark-gray silt, sand, and clay). They include frequently flooded areas (such as stream banks and first bottoms), abandoned channels, and outer edges and banks of some low terraces. It would be possible to map some of the areas of alluvium as alluvial terraces or as recent alluvial terrace extensions of older terraces. The topographic relationships of the alluvial deposits along Deep River near Cumnock are shown on plate 3.

Alluvium is now being removed by the Deep River and by most of its tributaries faster than it accumulates; bedrock is exposed at many places along the bottoms and sides of the river channel. However, this is not true of the Cape Fear River and its tributaries above Buckhorn Dam.

STRUCTURE

GENERAL FEATURES

The Deep River Triassic basin is a wedge-shaped block of sediments that occupies a northeast-trending trough-like depression in the pre-Triassic rocks of the Piedmont plateau. Within this block the Triassic sedimentary rocks generally dip southeastward at an average angle of almost 15°. Most of the bottom and the northwestern edge of the block are formed by the irregular sedimentary contact between these sediments and the underlying pre-Triassic igneous and metamorphic rocks. The southeastern side of the block is formed by the Jonesboro border fault, which has a minimum vertical displacement of 6,000 to 10,000 feet. Longitudinal faults and cross faults cut the Triassic block into rectangular subblocks.

The sedimentary wedge of the Deep River basin is divided into three structurally-distinct segments: the Durham basin, the Colon cross structure, and the Sanford basin (see fig. 28). In the Durham and Sanford basins the Triassic sedimentary rocks are relatively thick; they reach a maximum thickness of about 10,000 feet in the Durham basin, according to Prouty (1931, p. 484), and are 6,000 to 8,000 feet thick in the Sanford basin; the base of the Triassic beneath these basins is correspondingly deep. In the Colon cross structure, which is near the center of the Deep River basin, the Triassic sediments are no more than 4,000 to 5,000 feet thick, and the base of the Triassic is correspondingly shallow.

The Durham and Sanford basins are shallow, northeast-trending half-synclines, with the southeast limbs missing. Although there are many interruptions in the regional strike and dip of the beds, which were caused by faults and folds, the sedimentary rocks in the northwestern parts of these basins have southeast dips averaging more than 20°, whereas the rocks in the southeastern parts of the basins are nearly flat. The

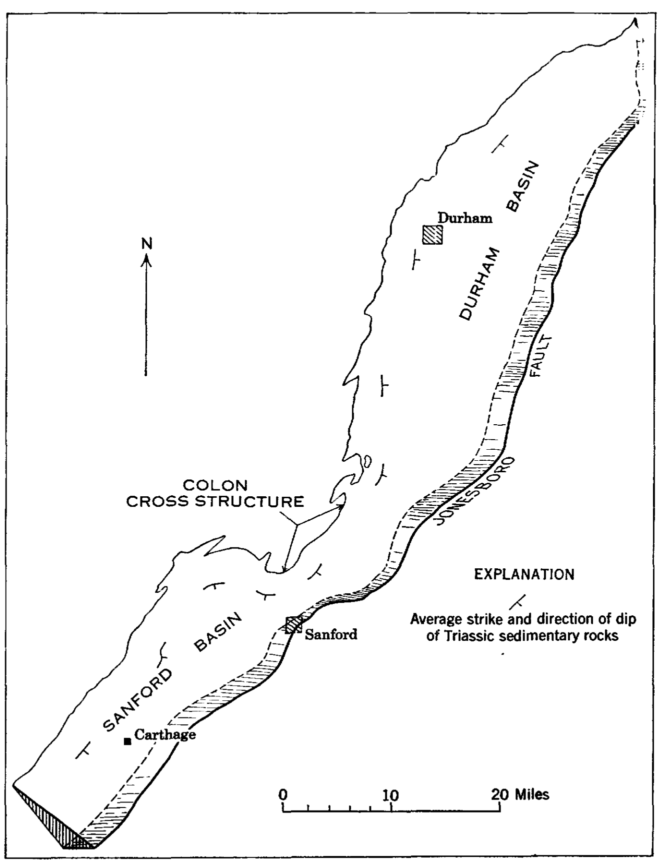


FIGURE 28.—Major structural features of Deep River Triassic basin.

Colon cross structure is a northwest-trending anticlinal fold in the Triassic sediments and in the crystalline rocks beneath them, forming a constriction across the center of the Deep River basin. Although it has subsequently been modified by faulting, this fold is still reflected in the northwest strikes and the southwest dips of strata at the northeastern end of the Sanford basin.

FAULTS

Two systems of normal faults have broken the Deep River Triassic wedge into structurally discordant fault blocks. Northeast-trending longitudinal faults, roughly parallel to the Jonesboro fault, are present in the northwestern part of the Sanford basin (see pl. 4), and similar faults have been mapped by Harrington (1951, p. 153–156) at the northwestern edge of the Durham basin. Northwest-trending crossfaults, which are commonly followed by diabase dikes, are present throughout the Sanford basin and the Colon cross structure, and probably they are abundant in the Durham basin as well. Tilting and differential subsidence of blocks within the rectangular fault framework produced by these two fault systems (accompanied by local bending and drag folding of the Triassic strata) have resulted in many variations from the regional strike and dip of the beds, in variable displacements along faults, and in abrupt changes of attitude and relative elevation of beds in the Deep River basin.

LONGITUDINAL FAULTS

Six major longitudinal faults, the Jonesboro, Deep River, Gulf, Indian Creek, Governors Creek, and Crawley Creek faults, as well as several other faults that branch from the Crawley Creek and Governors Creek faults, and a number of minor longitudinal faults, are within the area shown on the structure map (pl. 4). The northwest side is downthrown on all except the Gulf fault and a few minor faults. The Gulf, Jonesboro, and a few minor faults are offset by cross faults, but the other longitudinal faults are younger than the cross faults and are not offset.

JONESBORO FAULT

The Jonesboro fault is one of the most important structures in North Carolina. It forms the contact between the Triassic and pre-Triassic rocks along the southeastern side of the Deep River Triassic basin for more than 100 miles. Within the mapped area, it has a vertical displacement of at least 6,000 to 8,000 feet, which is the maximum thickness of Triassic strata in the Sanford basin.

Campbell and Kimball (1923, p. 55–60) mapped, described, and named the Jonesboro fault for the village of Jonesboro, which is now a part of the city of Sanford. This fault passes through the eastern part of Sanford, and it was accurately located in a cut along the Atlantic Coast Line Railroad near the Lee County courthouse. Northeast of Sanford, the fault forms the contact between fanglomerate in the upper part of the Sanford formation and Carboniferous (?) granite or pre-Triassic schist, and it was traced to the eastern limit of the mapped area. Southwest of Sanford most of the fault trace is concealed beneath the post-Triassic high-level deposits, and it was located only where it crosses the Seaboard Railroad, 2 miles south of Sanford; along the county road 2 miles north of Lemon Springs; and at a point where it crosses the newly-paved highway from Carthage to Cameron, 4 miles east of Carthage.

An excellent exposure of the Jonesboro fault is in a road cut near a railroad crossing 1 mile east of Corinth, where this fault forms the contact between light-gray Carboniferous (?) granite and brown and gray banded Triassic claystone interbedded with granite boulders and granitic debris apparently derived from the granite mass across the fault. The fault surface here is sharp and fairly straight, and it strikes N. 60° E. and dips 67° NW. Shear surfaces, parallel to the fault, are present both in the granite and in the claystone within 5 feet of the fault, and the Triassic strata are dragged up along the fault. Another good exposure is on the highway from Carthage to Cameron, where the fault forms the contact between very light-gray pre-Triassic talcose schist and Triassic fanglomerate composed of rounded blocks of metamorphic rocks embedded in a grayish-red matrix. This exposure is shown in figures 29 and 30. The fault strikes N. 40° E., dips 65° NW and diverges slightly from the cleavage of the adjacent pre-Triassic rocks that strike N. 55° E. and dip 65° NW. In both of these exposures the fault zone is only a few feet wide and apparently most of the movement occurred along a single surface.

A detailed study of the trace of the Jonesboro fault shows that it is cut and offset by cross faults and dikes at many places. One of the most conspicuous offsets, which measures at least 400 feet, is along a dike near the Sanford water works. Many other large offsets in this fault have been observed along the southeastern side of the Colon cross structure (see pl. 4). It is probable that some of the cross faults and dikes in the Sanford basin produce offsets in the Jonesboro fault that are concealed by the post-Triassic deposits southwest of Sanford.

DEEP RIVER FAULT

The Deep River fault is also a regionally-important structure in the Deep River coal field. It has produced horizontal offsets in the coal outcrops, southwest of Carbonton and north of the McIvor mine, amounting to

FIGURE 29.—Jonesboro fault on highway from Carthage to Cameron, 3 miles east of Carthage. View looking southeast. Dark-colored Triassic rocks in foreground faulted against light-colored pre-Triassic rocks in background; fault is near center of photograph. Post-Triassic deposits cap hill in background.

about a mile and a half at each locality, and it has raised the coal in the center of the field from a depth of more than 3,000 feet below sea level on the northern side of the fault to a depth of less than 2,000 feet below sea level on the southern side of the fault (see pl. 2, section A–A′). Near the McIvor mine the vertical displacement in the coal beds along this fault is about 2,200 feet, and south of the Murchison mine it is about 2,000 feet. South of Carbonton, however, the vertical displacement of beds in the upper part of the Cumnock formation is less than 500 feet because an anticlinal drag fold has developed locally in the Cumnock shale along the fault and has absorbed most of the fault displacement. Calculated vertical displacements along this fault are shown on the structure map (pl. 4).

The 17-mile trace of the Deep River fault from the vicinity of Woodard Bridge, where it enters the Triassic basin, to the area 2 miles east of Putnam, where the fault dies out, is in part an easily identified contact between different rocks and different formations, and in part an obscure contact between similar rocks of the same formation. Near Woodard Bridge it forms the contact between basal Triassic sandstone and conglomerate and pre-Triassic schist; at the bend of Deep River, southeast of the Carolina mine, it brings shales of the Cumnock formation against the basal conglomerate of the Pekin formation.

The best exposure of this fault in the entire field is in a cut on the Atlantic and Yadkin Railroad near the McIvor mine, where it separates red and brown sandstones of the Sanford formation from gray shales of the Cumnock formation and is followed for a short distance by a diabase dike. For a distance of 7 miles southwest of this locality, the fault trace is within the Sanford formation and is bounded on both sides by similar rocks. Nevertheless, it is possible to determine the approximate location of the fault in this part of the field by detailed mapping and by the use of such criteria as interruptions in dikes and dike patterns, diabase along the fault, shatter zones (in which the principal fractures are parallel to the fault and secondary fractures are normal to it), zones of disorganized rocks having diverse strikes and dips, discordance of regional strikes and dips on the two sides of the fault, and interruptions in the continuity of beds. South of Carbonton, this fault passes along the crest of the previously described anticlinal fold in the upper part of the Cumnock formation. South of Haw Branch and Glendon,

FIGURE 30.—Close-up of Jonesboro fault exposure 3 miles east of Carthage. Same exposure shown in figure 29. Triassic fanglomerate in Sanford formation (dark-colored) faulted against pre-Triassic talcose or pyrophyllitic schist (light-colored). Fault trends oblique to plane of photograph, dips about 65 degrees to the left (northwest).

it forms an easily recognized contact between the Cumnock and Pekin formations.

The part of the Deep River fault that causes the offset in the Cumnock formation between the McIvor and Carolina mines was first named the "Deep River fault" by Campbell and Kimball (1923, p. 35–40). The twofold outcrop of the Cumnock formation southwest of Carbonton was attributed by them to another fault, which they called the "Carbonton fault." They believed the Carbonton fault extended northeastward to the vicinity of Gulf, where it was responsible for a bifurcation of the Cumnock outcrop. Recent drilling has shown that the so-called Carbonton fault does not extend northeastward toward Gulf, and detailed surface mapping shows that the apparent bifurcation of the Cumnock formation near Gulf does not actually exist. All the available evidence strongly suggests that the Deep River fault and the so-called Carbonton fault of Campbell and Kimball, which produce similar displacements in the Cumnock formation on opposite sides of the field, are actually different segments of the same fault. Therefore, the name "Deep River fault" is now applied to the entire structure.

If the Deep River fault continues northeastward from Woodard Bridge for at least 7 miles, it may account for the existence of an embayment of Triassic rocks north of Moncure, which is separated from the main Triassic basin by a peninsula of pre-Triassic rock (see pl. 1). This embayment may be a downfaulted Triassic segment along the northern side of a northeast extension of this fault. Such an interpretation is suggested by the relative straightness of the south side of the embayment (which is approximately in the line of strike of the Deep River fault), by the existence of a severely brecciated zone where the projected fault crosses the county road 2 miles north of Moncure, and by the confinement of Triassic basal conglomeratic beds to the northwestern side of the embayment. If the displacement along the Deep River fault in this area is as great as it is in the Sanford basin, this embayment may be entirely the result of faulting. It could represent a sedimentary fill of a pre-Triassic valley, as suggested by Harrington (1947, p. 20), but the available structural and stratigraphic evidence favors Russell's (1892, p. 94) view that this embayment is at least partly the result of faulting.

In several places the Deep River fault is followed for short distances by small diabase masses, which were intruded after the fault was formed. This fault consistently causes interruptions in the continuity of northwest-trending dikes in the Sanford basin, however, and unlike the Jonesboro fault, it is not crossed or offset by these dikes or by cross faults. This suggests that the Deep River fault developed later than the northwest-trending cross faults, that the observed interruptions in the dike pattern along the Deep River fault reflect preintrusive interruptions and offsets of the cross faults which are followed by the dikes, and that the Deep River fault was formed later than the Jonesboro fault.

GULF FAULT

The Gulf fault extends from the vicinity of Woodard Bridge, where it causes a half-mile offset in the basal Triassic contact, to 1 mile south of Carbonton, where it passes into a syncline in the Cumnock formation. It is the only major longitudinal fault on which the southeast side is downthrown. From Cumnock to Carbonton this fault forms the contact between the Cumnock and Sanford formations and cuts the coal beds a few hundred feet from the outcrop. Mine workings in this part of the field have encountered folds, branch faults, or intrusions along this fault, and they have been abandoned. A branch of the Gulf fault has been encountered in the upper workings of the Cumnock mine and probably continues eastward along the Deep River (see pl. 3), but the main Gulf fault in this part of the field may be farther north within the Pekin formation. A branch fault, which joins the Gulf fault near the Deep River mine, forms the northwestern edge of the Triassic basin west of Carbonton.

Information obtained in early drilling and mining at Gulf led Chance (1885, p. 40–42) to postulate the existence of a fault that was near the coal outcrop and had the downthrow on the southeast, similar to the Gulf fault. These early drill records were lost, however, and Campbell and Kimball (1923, p. 34) discounted Chance's concept. Recent drilling southeast of Gulf, which has shown that the coal in this area is several hundred feet deeper than expected, indicates that there is a major longitudinal fault near the coal outcrop, as Chance suggested. Furthermore, the outcrop of the Cumnock formation near Gulf is not as wide as expected; thus it is now assumed that part of it has been cut out by faulting. These facts, together with the other surface indications of faulting and the dislocations of the coal beds observed in mine workings, indicate beyond question that the Gulf fault exists, although its location and displacement in some parts of the field are uncertain.

The vertical displacement along the Gulf fault increases from 50 feet or less, south of Carbonton, to about 600 feet, at Gulf, and to 750 feet, between Gulf and Cumnock (see pl. 4). Near Woodard Bridge, the vertical displacement on this fault amounts to about 700 feet. The branch of the Gulf fault encountered in the upper part of the Cumnock mine, shown on plate 3, has a vertical displacement of about 100 feet, and a similar branch fault encountered in drill hole BMDH E-1 has a displacement of about 80 feet (see pl. 2, sec. A–A′).

For most of its length, the trace of the Gulf fault is concealed by alluvium, terrace deposits, or intrusives, and its approximate location is known only through information obtained in drill holes and mine workings. It was located in a clay pit of the Chatham Brick and Tile Company 1 mile east of Gulf, where it forms the contact between red and brown claystone or gray arkosic sandstone of the Sanford formation and contorted gray shale of the Cumnock formation. The surface of the fault, which until recently was exposed in a part of this pit, had a strike of N. 85° W. and a dip of 60° SW. and was offset about 75 feet by a cross fault trending N. 28° W. The position of the Gulf fault was located at Gulf also, where it is followed by a diabase dike. A cut on U. S. Highway 421 at Gulf, on the western side of the Gulf fault, shows gray and black shale overlying the coal beds in the Cumnock formation, which have been cut and titled by minor faults along the Gulf fault (see fig. 31).

Cross faults and dikes cut and offset the Gulf fault near Gulf, and cross faults offset the branch of this fault that forms the Triassic boundary west of Carbonton. The Gulf fault apparently is older than the cross faults, and it may have been formed at about the same time as the Jonesboro fault.

INDIAN CREEK FAULT

The Indian Creek fault crosses the northwestern tip of the Sanford basin and affects only the Pekin formation within the basin. It is a remarkably straight fault, which causes a re-entrant in the basal Triassic contact where it enters the Triassic basin north of Carbonton and causes another re-entrant in this contact where it leaves the basin north of Cumnock. In the center of the basin it causes a duplication in the outcrop of a distinctively coarse, gray arkosic sandstone and adjacent beds in the middle of the Pekin formation, and its trace is marked by a belt of greatly disarranged rock, which is well exhibited on U. S. Highway 421, one mile north of Gulf. One of two similar faults mapped by Harrington (1951, p. 153) at the western edge of the Durham basin may be a northeastward extension of the Indian Creek fault.

Calculated vertical displacements on the Indian Creek fault, which is downthrown on the northwestern side, are 800 and 1000 feet, as shown on the structure map (pl. 4). There is no evidence that this fault is cut or offset by cross faults. Perhaps it was formed contemporaneously with the Deep River fault.

Half a mile north of the Indian Creek fault, another, and similar, fault (with smaller displacement) crosses the margin of the Triassic basin east of Goldston. The Triassic border in this area is formed by a fault having the downthrown side on the south; this fault is offset by dikes and cross faults and may be of the same age as the Gulf fault.

GOVERNORS CREEK FAULT

The Governors Creek fault branches from the Deep River fault in western Lee County, 4 miles east of Carbonton. It extends southwestward along the middle of the Sanford basin for at least 17 miles—it passes along the lower course of Governors Creek half a mile east of Horse Shoe Bridge, follows McLendons Creek for 2 miles, and disappears beneath the post-Triassic high-level deposits 4 miles southwest of Carthage. Northeast of Horse Shoe Bridge the trace of this fault lies entirely within the Sanford formation, but it was located (approximately) by mapping dislocations in beds and dikes and by tracing zones of fractured and folded rock. For 3 miles southwest of Horse Shoe Bridge this fault causes a duplication in the outcrop of the Cumnock formation, and it forms the northern edge

FIGURE 31.—Gulf fault zone on U. S. Highway 421, at Gulf. Exposure on northeast side of road about 1,325 feet south of Norfolk Southern Railroad overpass. Gray and black shale of Cumnock formation cut by four faults with probable displacements of several tens of feet. Main Gulf fault is 150 feet to the right of the photograph. Cumnock coal bed crops out 100 feet to the left of the area shown by the photograph and lies beneath the shale in this exposure.

of one of these outcrops (see pl. 1). West of Carthage, this fault causes another duplication in the Cumnock outcrop.

Where the Governors Creek fault crosses State Highway 27, about 2 miles west of Carthage, the surface of apparent main displacement strikes N. 40° E. and dips 80° NW. Other faults in this zone strike N. 60° E. and dip 50° NW. Drag folds are present in beds on both sides of the fault zone. A similar zone of faulting and folding marks the place where the Governors Creek fault crosses a county road half a mile south of Horse Shoe Bridge.

Available evidence indicates that the northwestern side of the Governors Creek fault is consistently downthrown. Calculated vertical displacements of 700 feet west of Carthage and 1,300 feet southwest of Horse Shoe Bridge (shown on the structure map, pl. 4) suggest that the average displacement on this fault may increase toward the northeast, but abrupt changes in the magnitude of the displacement have resulted from differential movements of blocks between cross faults on the two sides of the Governors Creek fault. East of the Gardner mine this fault has the important economic effect of raising the coal beds several hundred feet on the southeast side of the fault. The exact amount of this displacement can be determined only by diamond drilling.

No offsets in the Governors Creek fault have been observed. This fault probably was formed after the formation of cross faults and at the same time as the Deep River fault.

About 2 miles west of the Governors Creek fault, another longitudinal fault begins west of Horse Shoe Bridge and extends southwestward for at least 10 miles. The northwestern side of this fault is downthrown: this displacement causes a duplication of the outcrop of beds in the middle part of the Pekin formation west of Carthage and causes an abnormally wide outcrop area. West of Horse Shoe Bridge, the unusually wide outcrop of the Cumnock formation is caused partly by this fault and partly by flat dips of the beds.

CRAWLEY CREEK FAULT

The Crawley Creek fault branches from the Deep River fault 5 miles northwest of Sanford and extends southwestward 15 miles to its junction with the Governors Creek fault, 1 mile south of Coles Mill. East of Coles Mill, the Crawley Creek fault forms the contact between rocks in the lower part of the Cumnock formation, on the northern side of the fault, and rocks in the upper part of the Pekin formation, on the southern side of the fault. The vertical displacement along this part of the fault is about 500 feet, as shown on the structure map (pl. 4). Where it crosses Crawley Creek, this fault is bounded on the north by beds in the lower part of the Sanford formation, and it is bounded on the south by beds in the lower part of the Cumnock formation. The vertical displacement of beds at that locality is about 800 feet. In Lee County, the fault is bounded on both sides by similar beds within the Sanford formation, and its displacement is not known. Abrupt changes in the magnitude of the displacement along this fault, as along the Governors Creek fault, are the result of differential movements of blocks on either side of the fault.

Other longitudinal faults branch from the Crawley Creek fault in eastern Moore County and western Lee County. On two of these faults the northern side is downthrown (as it is on the Crawley Creek fault); this results in duplications in the outcrop of the Cumnock formation from 3 to 5 miles north of Carthage. The displacements on other longitudinal faults in this area are not known, although the existence of such faults is indicated by dislocations, fractures, and folds in the rocks, and by discontinuities in the dikes. Northwest of Carthage, a 2-mile interval without a trace of the Cumnock formation suggests that on one of these faults the southern side is downthrown and that the Cumnock formation is cut off below the surface on the southern side of the fault and has been eroded away from the northern side. The fault on which this displacement is believed to exist is about 2 miles northwest of Carthage (see pl. 1). Although the evidence for this interpretation is not conclusive, for reasons previously stated it is more likely that the gap in the Cumnock outcrop in this area is caused by faulting than it is that this gap is a result of facies changes that make the Cumnock formation locally resemble the Sanford or Pekin formations.

The Crawley Creek and adjacent faults do not appear to be cut, or offset, by dikes or cross faults. They are a part of the system of longitudinal faults that includes the Governors Creek and Deep River faults, and all the faults in this system probably were formed at about the same time.

CROSS FAULTS

Cross faults are abundantly distributed throughout the Deep River coal field; the northeast-trending segments of the Triassic wedge that are bounded by the longitudinal faults are cut into narrow blocks by these cross faults. In the Sanford basin the cross faults generally trend N. 25°–40° W., whereas in the Colon cross structure and in the southern Durham basin they trend N. 15°–20° W. They are identified by offsets in contacts, by discontinuities in beds, by zones of shattered and contorted rock, and by differences in strikes and dips of beds on opposite sides of faults. Many of them are followed by dikes. Most of the cross faults that were mapped are shown on plate 4, but there are probably many more of these faults that were not mapped, particularly where exposures are poor and where the rocks are concealed by post-Triassic deposits.

Vertical displacements of beds are less than 50 feet on most cross faults, but displacements of several hundred feet exist on a few faults, thus causing major horizontal offsets in formations. An offset of about half a mile in the outcrop of the Cumnock formation north of Brickhaven apparently is caused by a cross fault beneath the alluvium east of the Carolina Power and Light Company plant (see pl. 1). Between Carthage and Glendon, a cross fault, which has been cut into disconnected segments and offset by longitudinal faults of the Deep River-Governors Creek fault system, produces a half-mile offset in the basal Triassic contact 2 miles west of Glendon and forms the southwestern limits of four successive outcrops of the Cumnock formation south of Glendon. The combined effects of several hundred feet of upthrow on the southwestern side of this cross fault, and of successive upthrows totaling several thousand feet on the six longitudinal faults in this area, have displaced the Cumnock formation halfway across the Sanford basin.

In the Deep River Triassic basin, as a whole, there is little consistency in the direction of displacements on the cross faults, but in some belts of closely spaced cross faults most of the individual fault displacements are in the same direction. For example, the west side is downthrown on most of the cross faults and dikes located from 2 miles west of Sanford to 2 miles east of Sanford. The effect of the individual displacements in this belt of cross faults, which is at the eastern end of the Sanford basin, is to progressively drop the Triassic sediments in the Sanford basin below those in the Colon cross structure, thereby accentuating the anticlinal constriction formed in the Triassic sedimentary wedge by the Colon cross structure.

Displacements on cross faults in the Deep River coal field, like those on the longitudinal faults, commonly change considerably within short distances. In the Cumnock mine, a fault having a vertical displacement of 30 feet in the center of the mine has almost no displacement 1,200 feet away (see pl. 5). In the lower part of the Carolina mine, a fault having 50 feet of vertical displacement in the main slope has only about 10 feet of vertical displacement 500 feet away (see pl. 6). A zone of cross faults southwest of Cumnock (shown on pl. 4), has a combined vertical displacement of about 300 feet near the Deep River fault, but 2 miles farther north the total combined displacement on these faults is probably not more than a few tens of feet. These abrupt changes in displacements along faults are of importance to the mine operator, because a fault that displaces a coal bed several tens or even hundreds of feet at one place may cause so little displacement in the coal bed somewhere else that the mine workings can easily be extended across the fault and can be maintained in the coal bed with little interruption of the grade or level of the workings.

Abrupt changes in the displacements along many faults in the Deep River basin are a result of independent movements of the different fault-bounded blocks. Such movements probably occurred mainly in the final stages of faulting when the Deep River, Governors Creek, and other late longitudinal faults were forming and when the cross faults and early longitudinal faults were already in existence. The final subsidence of the Deep River Triassic wedge was accomplished by different amounts of subsidence of the different constituent fault blocks and by differential warping and tilting of these blocks.

FOLDS

Both longitudinal folds and cross folds are present in the Deep River coal field. The Colon cross structure (a faulted anticline) is the largest cross fold, and the Sanford basin (a faulted syncline) is the largest longitudinal fold in the mapped area. These structures are of regional extent, and they probably affect both the Triassic and the underlying pre-Triassic rocks. Many other folds of small amplitude and limited extent are present along, or near, the longitudinal faults or cross faults or within blocks bounded by these faults. These minor folds probably affect only the Triassic rocks.

COLON CROSS STRUCTURE

The Colon cross structure is basically an anticlinal cross fold that is reflected in the northwest strikes and southwest dips of strata north of Sanford and west of Colon and in the northeast strikes and southeast dips of beds east of Colon. It affects both the Triassic sediments and the crystalline floor beneath them. As stated previously, this fold has been modified and accentuated by later cross faulting, particularly in the vicinity of Sanford. Both the cross folding and the cross faulting have resulted from the subsidence of the Sanford and Durham basins relative to the Colon cross structure.

Campbell and Kimball (1923, p. 54–55) described and named the Colon cross structure. They recognized that it is, in part, a cross anticline that abruptly destroys the synclinal form of the basin west of Sanford, but they believed that this fold was broken near Colon by a major cross fault; east of this cross fault the formational contacts had been shifted several miles northward. The bases for the assumption of this important cross fault were stated as follows:

(1) The disappearance of the Cumnock formation when it reaches the system of dikes, shown on the map, two and three-quarter miles east of Sanford.

(2) The curious coincidence of the trend of these dikes directly toward the sharp angle in the lower boundary of the Pekin formation, where it turns from a northwest-southeast to a northeast-southwest direction (near Lee Brick and Tile Co. plant north of Sanford).

(3) The discordance in the dip and strike of the rocks on the two sides of the belt of dikes, the dips on the northeast side being at right angles to those on the southwest side.

(4) The apparent offset in the outcrop of the Cumnock formation from the point already described about one mile south of Colon to the prolongation of the belt of outcrop extending from Lockville (Lockport) southwestward parallel with and about one and one-half miles distant from the line marking the base of the Pekin formation.

The Colon cross anticline is indeed broken by cross faults and dikes, as shown on the structure map (pl. 4), but the evidence shows that these displacements do not exceed a few hundred feet and do not seriously disturb the continuity of the anticline. The criteria offered by Campbell and Kimball may be explained (without recourse to a cross fault having thousands of feet of displacement) as follows:

1. Although the Cumnock formation ends in a zone of dikes east of Sanford, its disappearance there is not primarily caused by faulting, but instead, it is a result of a lateral gradation of the formation into red and brown beds that are indistinguishable from the Pekin and Sanford formations.

2. The offset in the basal Triassic contact north of Sanford is neither great enough, nor in the proper direction, to be a result of the type of faulting that is postulated.

3. Discordances in beds across the zone of dikes and cross faults in the Colon cross structure are no greater than discordances of beds across other zones of cross faults where tilting and drag folding of rocks have occurred. Furthermore, the lithologic character of the sediments in this area indicates that these sediments were deposited in an alluvial fan. Many of the irregularities in bedding may therefore be of sedimentational rather than structural origin.

4. Beds identified as the Cumnock formation near Lockport are now believed to be Cumnock-like strata in the lower part of the Pekin formation. The Cumnock formation northeast of the Colon cross structure is near the center of the Triassic basin (as shown on pl. 4).

With this revised correlation and relocation of the Cumnock formation, the necessity for postulating a large displacement on a cross fault in the Colon cross structure no longer exists.

Detailed mapping northwest of the Sanford water works shows that a local angular discordance exists between beds in the Pekin formation and beds in the Sanford formation, and it shows that the lower part of the Sanford formation probably is missing in this area. This discordance is shown by the patterns of conglomerate and fanglomerate on the geologic map (pl. 1). It is true that minor irregularities in bedding usually are present where sediments are deposited in alluvial fans, but in this area the magnitude of discordance suggests that it may be the result of tilting and erosion of the underlying beds before the upper part of the Sanford formation was deposited. If this interpretation is correct, development of the Colon cross anticline began before Triassic sedimentation was completed, and it proceeded simultaneously with movements on the Jonesboro fault (these movements are recorded by textural variations in the late Triassic sediments).

The Colon cross anticline is truncated by the Jonesboro fault. This does not necessarily indicate that it was formed before the fault. If the tilting and down-dropping of the Deep River Triassic basin were accompanied by movements along this fault, then the Colon cross anticline may have formed at the same time as the fault by relatively greater subsidence in the Sanford and Durham basins than in the Colon cross structure.

SANFORD BASIN

The Sanford basin is a northeast-trending synclinal structure, which has been modified by longitudinal faulting and cross faulting accompanied by local tilting and drag folding of the Triassic sediments. Most of the southeastern limb of the syncline is missing. The bottom, or axis, of this structure is near the southeastern edge of the basin (see pl. 4). This axis is clearly defined for a distance of 4 miles, from 2 miles north of White Hill to 2 miles west of Tramway. Along this line the beds are generally horizontal. Southeast of this axis, the Triassic rocks have northwestward dips averaging about 10°; northwest of this axis, the beds have southeastward dips that become progressively steeper toward the northwest (except for local interruptions caused by faulting and drag folding) and they average about 20° along the northwestern side of the basin. Northwest of Tramway, the synclinal structure is complicated by cross faulting and cross folding of the beds, as indicated by the strikes and dips shown on the geologic map (pl. 1), and in the vicinity of Sanford the synclinal basin is terminated by the Colon cross anticline. Northwest of White Hill the synclinal axis passes beneath the post-Triassic high-level deposits.

Campbell and Kimball (1923, p. 50–51) recognized and described the synclinal structure of the Sanford basin, which they called the Carthage trough, as follows:

> At Carthage the east limb of the trough is lacking, having been cut off by the Jonesboro fault, as explained later, but the synclinal form is plainly apparent in the rather steeply sloping northwest side of the trough and the relatively flat bottom which is indicated by the slight dips recorded on the Carthage-Sanford road.
>
> From Carthage northeastward the trough is continuous and of approximately the same shape and width to the vicinity of Sanford, Cumnock and Gulf, where it is nearly cut off by a cross-anticline here called the Colon anticline, which corresponds in position and direction with a line connecting Woodard's Bridge and the Sanford Waterworks on the headwaters of Lick Creek, about three miles east of Sanford. The synclinal character of this end of the trough is shown by the semicircular shape of its northern extremity.

They did not note the synclinal axis and 4-mile belt of northwest-dipping rocks between White Hill and Tramway, but they reported (1923, p. 49) that both limbs of the syncline are present in the Wadesboro Triassic basin, and they cite this as an indication that the Sanford basin was also a complete syncline before it was cut off by the Jonesboro fault.

In this writer's opinion, the synclinal structure of the Sanford basin, like the anticlinal form of the Colon cross structure, may be largely a result of differential subsidence of the Triassic sedimentary wedge during the deposition of the beds. Textures of the Triassic sedimentary rocks indicate that the Jonesboro fault was active at least in late Newark time, and mineral compositions of these sediments show that pre-Triassic rocks east of the Jonesboro fault were being eroded during the late Triassic sedimentation. This suggests that the southeastern edge of the Sanford basin, at least during the late Triassic, was near the Jonesboro fault, that the Sanford basin at that time was a down-faulted block rather than a simple syncline, and that it had no more of a southeastern limb than it has now. Differential subsidence of the Triassic sedimentary wedge along a longitudinal axis, accompanied locally by drag and upward tilting of beds along the Jonesboro fault, would produce the existing synclinal structure of the Sanford basin, and differential subsidence along a cross axis would produce the anticlinal fold of the Colon cross structure.

MINOR FOLDS

The strata along most longitudinal faults and many cross faults are crumpled and drag folded. In many places along the Gulf fault the shale in the Cumnock formation is strongly contorted, and mines along this fault have encountered "rolls" in the coal beds. The largest fold associated with a single fault is the anticlinal structure along the Deep River fault south of Carbonton where, as previously mentioned, a flexure in the upper part of the Cumnock formation has locally taken up much of the displacement on the fault. Minor flexures, caused by bending and warping of the strata during subsidence, are present within many fault blocks in the field.

STRUCTURES AFFECTING THE COAL

Certain structures in the coal-bearing part of the Sanford basin and certain characteristics in structural behavior of the coal and overlying shale are of special importance to mine operators. Some of the more important structural features affecting the coal are discussed in the following paragraphs.

GRABEN BETWEEN DEEP RIVER FAULT AND GULF FAULT

The Deep River fault, the Gulf fault, and a branch of the Gulf fault northwest of Carbonton enclose a downfaulted block or graben wherein the Triassic rocks have been dropped as much as 750 feet below the adjacent rocks on the northwest and as much as 2,200 feet below the adjacent rocks on the southeast. This graben contains about three-fourths of the coal in the Deep River coal field, including practically all the coal that is more than 2 feet thick. For this reason, the future of the coal-mining industry in this field depends on the successful development of the coal resources of this downfaulted block, despite the fact that much of this coal is deeply buried.

Important faults in the coal-bearing part of this graben, and the depth, attitude, and thickness of the coal are shown on plate 7. Faults are shown as gray strips, bounded on one side by a black line to indicate the surface trace of the fault and on the other side by a red line to indicate the approximate intersection of the fault with the Cumnock coal bed. The distance between the red and black lines (or the width of the gray strip between them) is determined by the dip of the fault and the depth of the coal. Structure contours show the distance of the top of the Cumnock coal bed (main bench) above, or below, sea level. Where the depth of the coal is well known, the contours are solid; otherwise they are broken. Patterns on this map show the thickness of the main bench of the Cumnock coal bed.

Structurally, the downfaulted block between the Gulf and Deep River faults is a canoe-shaped graben, wherein the coal beds are near the surface at each end but are more than 3,000 feet deep in the center. Beds within this block generally strike northeast and dip southeast at an average angle of about 11°, but at each end of the block they are complexly folded. At the southwestern end, south of Carbonton, is the previously-described anticline along the Deep River fault and the adjacent, complementary syncline at the end of the Gulf fault. Structure contours on plate 7 show the forms of these folds in the Cumnock coal bed. At the northeastern end of the graben is a synclinal structure that is partly formed by the sweeping change in strike of formations on the west flank of the Colon cross anticline. North of the Carolina mine, this synclinal structure has been accentuated by a sharp, plunging trough that probably was formed by local squeezing and bending of the strata during subsidence of the graben. This fold is shown in detail by structure contours at 100-foot intervals on plate 3. Many other irregular warps in the beds on the edge of this trough have been encountered in the Carolina mine and are shown by structure contours at 10-foot intervals on the map of the Carolina mine (pl. 6).

Cross faults cut the graben between the Gulf and Deep River faults into sub-blocks. Vertical displacements are as much as 200 feet on some of these faults, but most faults have displacements of only 30 to 100 feet. Poor surface exposures and incomplete subsurface data make it impossible to obtain accurate estimates in regard to displacements in the coal beds along most of these faults. Therefore, the offsets in structure contours along the cross faults shown on plate 7 should be regarded as tentative estimates of the magnitude of displacements. The abrupt changes in displacements along faults in the Carolina mine (see pl. 6), which are a result of differential bending and tilting of the various fault blocks, show that it is practically impossible to predict exact displacement prior to mining or drilling. Additional cross faults, not shown on the map (pl. 7), probably exist near the ends of this graben.

The best mining conditions in the Deep River field are in the center of the graben between the Gulf and Deep River faults. Relatively large sub-blocks in that area contain coal at least 36 inches thick that has a rather uniform dip of 10° to 12°. Unfortunately, this coal is deep. The shallowest coal is near the ends of this graben where folding and faulting are so intense that much of the coal is not recoverable. Mining conditions encountered in the Carolina mine at the northeast end of the graben are worse than should be found farther west, where the structure is more simple.

STRUCTURES ALONG GULF FAULT

As noted previously, the Gulf fault closely parallels the coal outcrop from Cumnock almost to Carbonton. For most of that distance it cuts the coal a few hundred feet from the outcrop and drops it several hundred feet, as illustrated in plate 2, section A–A′. Most of the coal in the graben southeast of the Gulf fault is too deep to be reached efficiently by a slope from the northwestern side of this fault. Most of the coal between the Gulf fault and the coal outcrop is not minable because of branch faults, drag folds, and intrusions along the Gulf fault. Faults encountered in the Gulf mine, shown in figure 32, are typical of structures present along most of the coal outcrop.

STRUCTURES SOUTH OF DEEP RIVER FAULT

The coal south of the Deep River fault is only about half as deep as the coal on the northern side of the fault, as shown in plate 2, section A–A′, and therefore it is more easily accessible than some of the coal in the graben between the Gulf and Deep River faults. It is cut by Governors Creek and Crawley Creek faults and by many cross faults and dikes, but structurally it probably is no more complicated than the coal in the graben. It is unlikely that much coal south of the Deep River fault is thick enough to be mined at a profit, even though it is not as deep as coal north of the fault.

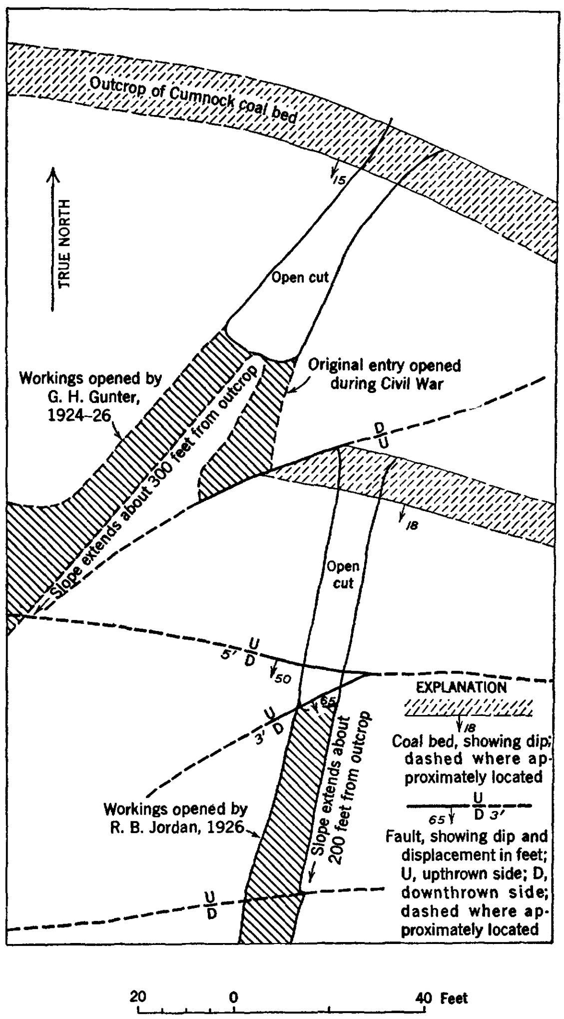


FIGURE 32.—Faulting along coal outcrop at Gulf mine.

STRUCTURAL BEHAVIOR OF THE COAL AND RELATED SHALE

The structural behavior of the coal and overlying shale in the Cumnock formation is a matter of the utmost importance to the mine operator because it determines the characteristics of structures in, and near, the coal. Thin-bedded and fissile shale in the upper part of the Cumnock formation are less competent to transmit stresses than are the thick-bedded claystone, siltstone, and sandstone of overlying and underlying formations. Slippage along the closely-spaced bedding surfaces of the shale facilitates folding rather than faulting. For this reason, faults commonly pass into folds upon entering the shale, as in the large fold along the Deep River fault south of Carbonton, which has already been described. Similarly, many faults in and near the coal beds, such as some of the faults shown on the map of the Carolina mine (pl. 6), pass abruptly into folds both vertically and laterally.

In general, folds are probably more abundant and faults are less continuous in the coal and adjacent shale than they are in the overlying Sanford formation. The continuity and the magnitude of displacements along many faults in the coal-bearing part of the Sanford basin may not be the same at the surface as they are in the coal beds after the faults have passed through almost 500 feet of shale overlying the coal.

Closely-spaced, nearly parallel fractures, commonly called cleats, are present in the Deep River coals. These cleats are most numerous in the main bench of the Cumnock coal bed, which is lowest in ash; they are less abundant in the higher-ash coals in the lower benches of the Cumnock coal bed and in the Gulf coal bed. They are interrupted by bony, or shaly, partings in the coal. Because of these cleats, the coal in the main bench of the Cumnock coal bed can usually be peeled off in sheets measuring an eighth of an inch to an inch thick, that crumble into rectangular biscuits when handled.

In the Carolina mine, the cleats generally extend from the top to the bottom of the main bench, as shown in figure 33. Strikes and dips of the cleats in the Caroline mine are plotted on plate 6. They have an average trend of N. 20° E. in the upper part of the mine, N. to N. 20° W. in the center of the mine, and N. 45° W. in the lower part of the mine, making angles of 25° to 50° with the strike of the beds. They generally dip 65° to 75° E., making angles of 80° to 90° with the bedding. Strikes and dips of the cleats are disorganized near faults; locally, the cleats are folded. These fractures probably were formed during the subsidence and warping of the Deep River trough and before the cross faults and the late longitudinal faults developed.

STRUCTURAL DEVELOPMENT OF THE DEEP RIVER BASIN

GENERAL REVIEW OF THE PROBLEM

The attitude of the Triassic rocks in the Deep River basin is partly a result of the primary structure acquired during deposition and partly a result of post-depositional deformation. Most geologists have agreed that deformation probably initiated and accompanied the deposition of the Triassic sediments in the Deep River and other eastern Triassic basins, but they have not agreed either as to the magnitude of the Triassic deformation or as to the size and shape of the resultant basins in which these sediments were deposited. Post-depositional faulting and tilting of the Triassic basins have modified and obscured their original form, just as post-depositional erosion has modified and obscured their original extent.

Two concepts have been proposed for the structural development of the Deep River basin. Campbell and Kimball (1923, p. 60–64) regarded the basin of deposition for the Triassic sediments as a simple downwarped trough, wherein no important faulting occurred until after the Triassic sedimentation was completed. This idea was similar to that proposed earlier by Davis (1898, p. 38–39) to explain the origin of the Connecticut Triassic basin, which is structurally similar to the Deep River basin, and it was also used by Roberts (1928, p. 161, 163) to explain the development of the Virginia Triassic basins. According to Campbell and Kimball, the present synclinal structure of the Sanford basin formed the west limb of this original trough, and the east limb was subsequently uplifted (along the Jonesboro fault) and eroded (see fig. 34). They believed that the Jonesboro border fault, and all other faults within the Deep River basin, were formed after deposition was completed and that they had no influence on the Triassic sedimentation.

A different concept was suggested by Prouty (1931, p. 485–490), who agreed that the Deep River basin originated as a gentle, symmetrical downwarp; however, he thought that continued subsidence took place mainly by faulting and produced a wedge-shaped trough (see fig. 34). He believed that the Jonesboro fault formed the eastern edge of the basin, at least during the later Triassic sedimentation, and that two-thirds of the movement on this fault occurred before the sedimentation was completed. According to Prouty, faulting within the basin, as well as the final movement on the Jonesboro fault, were post-depositional. He regarded the present southeast dip of the beds to be partly a result of tilting during deposition and partly a result of post-depositional tilting. This concept is similar to

FIGURE 33.—Cleats in the main bench of the Cumnock coal bed. Exposure in main slope of Caroline mine, 900 feet from portal. Coal is 38 inches thick. Bottom 3 inches of bench are bony and have fewer cleats. Coal is overlain by silty shale and is underlain by blackband.

that proposed earlier by Barrell (1915, p. 28–32) to explain the origin of the Connecticut Triassic basin, and it has received support from Longwell (1922, p. 235), from Wheeler (1937, p. 65–66), and most recently, from Krynine (1950, p. 117–120).

It is of considerable economic importance to determine which concept of the primary structure of the Deep River basin is most nearly correct. If the original edge of the basin was somewhere east of the Jonesboro fault and if that fault was formed too late to have any effect on the sedimentation, the coal beds in the Cumnock formation might be as thick, or thicker, near the Jonesboro fault as they are farther north in the area of mining and drilling, and important reserves of coal might be present in the southeastern part of the Sanford basin. If, however, the edge of the basin of deposition was formed by a scarp along the Jonesboro fault, the coal beds would probably grade southeastward into deltaic or fan deposits as they approached this fault, and important reserves of thick coal probably would not exist in the southeastern part of the Sanford basin.

The results of this investigation support the general concept of basin development proposed by Prouty. The evidence indicates that the Jonesboro fault formed the southeastern edge of the basin during much of the Newark epoch and that intermittent subsidence of the basin, accompanied by tilting, occurred along this fault during the deposition of the Triassic sediments. Post-depositional movement on the Jonesboro fault was followed by cross faulting, by longitudinal faulting, and by differential tilting of fault blocks in the basin. Igneous intrusions followed the faulting.

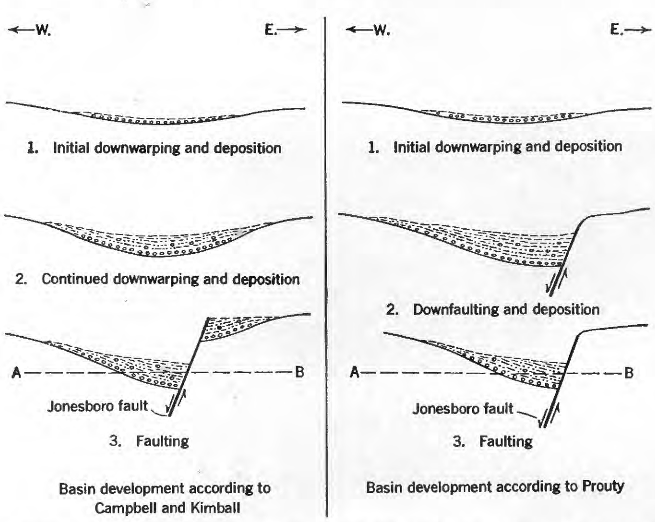


FIGURE 34.—Cross sections showing conceptions of the origin and development of the Deep River Triassic basin. Present surface of the basin is indicated by line *A–B*.

DEVELOPMENT OF THE TROUGH DURING DEPOSITION

Triassic sedimentation began in a shallow downwarped trough that formed in the pre-Triassic terrane. The floor of this trough was locally irregular, particularly in the Durham basin where islands of pre-Triassic rocks (probably hills in the basin floor) project through the lower Triassic deposits. Residual conglomeratic materials on the floor of this trough, which were derived from the disintegration of the underlying igneous and metamorphic rocks, were incorporated into the basal Triassic deposits. Some of these materials remained in place, others were reworked or carried into the trough by streams. Cross-bedding in the basal conglomerate beds along the western side of the basin shows that some of this material was transported from the west, but the probable source rocks for most of this debris are located no more than a few hundred or a few thousand feet away. Some of the materials in the basal conglomerate beds on the eastern side of the trough, which are now deeply buried, probably were transported from the eastern side of the initial trough.

Subsidence of the trough continued as the Triassic sediments were deposited. The following lithologic and structural features collectively suggest that this subsidence occurred intermittently along the Jonesboro fault, that the scarp along this fault formed the southeastern edge of the basin, and that the basin was filled with debris derived mainly from the highland area southeast of the fault.

1. Average grain size of sediments near the Jonesboro fault is much greater than the average grain size of sediments farther from the fault, as would be expected if the sediments were deposited by northwestward flowing streams. The coal and shale of the Cumnock formation grade southward into siltstone and sandstone at both ends of the Sanford basin; the claystone and siltstone of the Pekin and Sanford formations grade into sandstone and conglomerate near the fault. Conglomerate and fanglomerate are distributed along the Jonesboro fault at nearly all horizons in the Sanford formation and contain angular blocks as much as 8 feet across. Such deposits commonly accumulate at the foot of a steep scarp.

2. The composition of the Triassic fanglomerate correlates closely with the composition of the pre-Triassic rocks along the southeast side of the fault. This correlation would result if the highland area bordering the southeast side of the trough were eroded by short streams that crossed the fault scarp and dropped their loads near the margin of the trough.

3. Recurrent and laterally-extensive beds of conglomerate and coarse sandstone suggest recurrent uplift of

the source area for the sediments. Finer sediments were carried into the basin at times when the relief in the source area was low; coarse sediments were brought in when the fault scarp was rejuvenated and stream gradients in the source area were abruptly increased. The claystone and siltstone of the Pekin and Sanford formations, which are dominantly red or brown, consist of deeply-weathered materials that probably originated as a red soil on top of the crystalline rocks in the territory southeast of the Jonesboro fault. The coarse sandstone and conglomerate, which are dominantly gray or purple, are composed of fresher materials eroded from the bottoms and sides of canyons in the source area as streams cut through the red soil and into the fresh bedrock following the rejuvenation of the fault scarp. The relationship of erosion in the source area to the sedimentation in the Triassic basins has been discussed in detail by Krynine (1950, p. 186–192).

If this interpretation is correct, the coarse arkosic sandstone near the middle of the Pekin formation, which covers an extensive area in the Sanford basin, may indicate the first important uplift along the Jonesboro fault. The numerous beds of arkosic sandstone in the lower part of the Sanford formation probably correspond to recurrent rejuvenations of the Jonesboro scarp following a period of quiescence during deposition of the Cumnock formation.

4. The extreme angularity and friability of most constituents of the coarse Triassic sediments preclude a long distance of transport. Mineral grains in most of the Triassic sandstones are practically as fresh and angular as in the pre-Triassic rocks, and a large proportion of these grains are metamorphic rock fragments that probably could not withstand more than a few miles of stream transport without being thoroughly comminuted.

5. Offset relationships show that the Jonesboro fault is earlier than the other faults in the Deep River basin (with the possible exception of the Gulf fault). It is the only fault that is consistently paralleled by textural changes in the Triassic sediments. The other faults are clearly post-depositional.

Dips of strata in the Pekin formation along the northwestern side of the basin are consistently steeper than dips of strata in the Sanford formation along the southeastern side of the basin. This is illustrated by the structure sections on plate 2. In section *A–A′* of plate 2, the average southeast inclination of the Pekin formation at the northwestern edge of the basin is about 24°, whereas the strata in the Sanford formation at the southeastern edge of the basin are practically flat. In section *B–B′*, the Pekin formation at the northwestern edge of the basin has an average southeast dip of almost 40°, whereas the Sanford formation at the southeastern edge of the basin has an average southeast dip of 5° to 10°. It is probable that a part of the difference in dip between the younger and the older Triassic sediments (which gives the Sanford basin an apparent synclinal structure that has already been discussed) is a result of a progressive southeastward tilting of the trough during the subsidence along the Jonesboro fault that accompanied sedimentation. Most of this difference in dip, however, is probably a result either of differential downwarp of the trough on a longitudinal axis during deposition, or it is a result of post-depositional tilting that accompanied the late longitudinal normal faulting.

It is apparent that the Triassic sediments in the Deep River basin originally extended farther northwestward than at present. The present northwestern margin of the basin was determined mostly by post-Triassic erosion, and it probably is located several miles southeast of the edge of the original trough. Triassic sediments along the northwestern side of the Deep River basin are dominantly fine-grained, with the exception of the basal conglomerate beds, and they show little evidence of incursions of coarse material from a nearby source area to the northwest. The coal and black shale beds in the Cumnock formation are thickest along the outcrop near Cumnock, thus indicating that the center of the basin in which these beds were deposited was probably no closer than Cumnock to the Jonesboro fault and that the northwestern edge of the basin at that time was probably at least as far in the other direction. On the other hand, a deltaic accumulation of sand on top of the Cumnock coal bed between Gulf and Cumnock, which has been described previously, apparently was deposited by a stream from the northwest, thus suggesting that the margin of the trough was not far away. The available evidence indicates that the trough in which the Deep River sediments accumulated was probably several miles wider than the present basin, but it is doubtful that this trough was wide enough to include the Dan River basin, 75 miles away.

An alluvial fan, which was built by a stream from the southeast, existed in the trough east of Sanford during a large part of the deposition of the Newark group. Sediments within this fan are considerably coarser, on the average, than sediments in the Durham and Sanford basins, and the coarsest sediments within the fan are nearest the Jonesboro fault. This fan continued to grow until the Triassic sedimentation was nearly completed, and it formed a topographic barrier across the trough between the lower-lying Sanford and Durham basins. In mid-Newark time, coal and gray or black shale were deposited in these basins at the same time that red or brown sandstone and conglomerate were deposited on the higher ground formed by this fan. As a result of later cross folding, the coal and shale on the western side of this fan now have southwestward dips averaging 25°, whereas the conglomerate beds in the center of the fan have southeastward dips averaging 10° to 15°. Assuming that the coal was approximately horizontal when it was deposited, it follows that the surface of the fan had a northwest inclination of about 1° to 5°.

Toward the close of the Triassic deposition, the subsidence of the Durham and Sanford basins was greater than the subsidence of the area between them. This unequal downwarping produced the Colon cross anticline in the same area already occupied by the alluvial fan. Sediments as young as the lower Sanford formation, at the northeast end of the Sanford basin, were locally tilted as much as 12° west before the last of the fanglomerate was deposited along the Jonesboro fault. It is of interest to note that the Colon cross anticline is associated with a re-entrant, or northwestward bulge, in the Jonesboro fault east of Sanford. Wheeler (1939) has shown that similar anticlinal warps in some northern Triassic basins are associated with reentrants in border faults. He believes that here the Triassic sediments dropped less, because there was more friction or support from the footwall of the fault.

Total subsidence of the Deep River trough along the Jonesboro fault during Triassic deposition cannot be determined. The maximum thickness of Triassic sediments in the Sanford basin is 6,000 to 8,000 feet, and the maximum thickness of sediments in the Durham basin is almost 10,000 feet. The displacement of the Jonesboro fault was at least as great as the thickness of the existing sediments, plus an unknown thickness of Triassic sediments removed by erosion, but if the subsidence of the trough was accompanied by uplift of the block on the southeastern side of the fault, then the actual displacement may have been much greater than the original thickness of sediments in the basin. Flatness of beds in the southeastern part of the Sanford basin suggests that uplift of the source area may have been as important as subsidence of the basin during the final movements of the Jonesboro fault.

POST-DEPOSITIONAL DEFORMATION

The last movement on the Jonesboro fault was after deposition of the latest Triassic sediments now present in the Deep River basin. Triassic strata are upturned along the fault in many places as a result of this post-depositional movement. Minor fractures, parallel to the Jonesboro fault, exist in the adjacent Triassic rocks and present a further indication that this fault was active after these rocks were deposited. It is probable that the Gulf fault was formed at this time, accompanied by uplift and southeastward tilting of the northwestern side of the trough.

Following the cessation of movements on the Jonesboro and Gulf faults, northwest-trending cross faults were formed, which cut and offset the earlier faults, the Triassic sediments, and the pre-Triassic rocks. Although this faulting produced displacements of only a few tens or a few hundreds of feet, the cross faults apparently extended to great depths, because later they were the principal channels for the upward movement of the magma that formed the diabase dikes. Cross faulting was not a local phenomenon limited to the Deep River area; instead, it affected most of the eastern Triassic basins and the Piedmont plateau. Similar cross faults, cutting Triassic and pre-Triassic rocks in southern Pennsylvania and in Maryland, have been maped by Stose and Jonas (1939, p. 158–159), and they are also displayed on the geologic map of Virginia compiled by Stose (1928). Diabase dikes in the Piedmont of Georgia, mapped by Lester and Allen (1950), outline a pattern of joints or cross faults similar to that in the Deep River area, and White (1950, p. 1334–1336) has noted the effects of cross faulting in the Piedmont of western North Carolina.

A renewal of longitudinal faulting followed the development of the cross faults. Late longitudinal faults have been mapped in many eastern Triassic basins, and it is probable that many longitudinal faults developed in the Piedmont plateau. The Deep River, Indian Creek, Governors Creek, Crawley Creek, and other late longitudinal faults in the Deep River basin, which cut and offset the Triassic and pre-Triassic rocks and the cross faults, were formed at this time. Recurrent movements occurred locally on some parts of the disconnected cross faults as individual fault-bounded blocks subsided differentially. The Triassic strata were warped and drag-folded near the longitudinal faults. Additional southeastward tilting of sediments in the northwestern part of the Deep River basin probably accompanied this late longitudinal faulting, but it is unlikely that there was any appreciable regional tilting of the entire Triassic wedge at this time, because the attitude of most sediments in the southeastern part of the basin is within a few degrees of the probable initial dip.

The late longitudinal faulting was followed by igneous intrusions. Basic magma moved upward mainly along the cross faults and only locally along the longitudinal faults—possibly because the cross faults extended to greater depths or were less tightly closed than the longitudinal faults, and hence they were better conduits. The magma formed dikes along the faults and spread out as sills or sill-like intrusions in the Triassic sediments.

Normal faults, having displacements of no more than a few feet, were formed during the final episode in the structural development of the Deep River basin. These faults caused slight offsets in the intrusives and in the earlier faults. They also cut the Pliocene (?) high-level surficial deposits along the southeastern side of the coal field, and therefore some of them are probably of late Tertiary age.

SUMMARY OF STRUCTURAL EVENTS

The structural development of the Deep River Triassic basin may be summarized as follows:

1. Initial downwarp in the pre-Triassic terrane, accompanied by deposition of basal Triassic sediments.
2. Progressive subsidence of the trough along the Jonesboro fault, accompanied by southeast tilting of the trough and deposition of Triassic sediments.
3. Post-depositional movements on Jonesboro and Gulf faults.
4. Development of cross faults.
5. Development of late longitudinal faults, including the Deep River, Indian Creek, Governors Creek, and Crawley Creek faults.
6. Igneous intrusions.
7. Development of minor faults having displacements of only a few feet.

Steps 1 and 2 in the structural development of the Deep River basin occurred during the Newark epoch in the late Triassic; steps 3 to 6 probably occurred at the end of the Triassic or during the Jurassic, and step 7 probably occurred during the late Tertiary. The development of the Triassic basin in the late Triassic and early Jurassic is illustrated by the theoretical cross sections in figure 35.

GEOMORPHOLOGY

GEOMORPHIC FEATURES OF THE DEEP RIVER COAL FIELD

The sinuous edge of the post-Triassic deposits along the southeastern side of the Deep River coal field marks the boundary between two major physiographic provinces, the Piedmont plateau and the Coastal Plain. In the vicinity of the Deep River coal field the Piedmont plateau consists of a lowland developed on the Triassic sedimentary rocks and an upland developed on the pre-Triassic igneous and metamorphic rocks; the Coastal Plain is an upland developed mainly on post-Triassic deposits. The post-Triassic history of the Deep River field is partly recorded in the geomorphic features of both the Piedmont plateau and the Coastal Plain. It is necessary, therefore, to consider briefly the regional significance of the geomorphic features of these two provinces in order to determine the final episodes in the geologic development of the Deep River coal field.

TRIASSIC LOWLAND

The Triassic lowland is generally 50 to 200 feet below the Piedmont Upland (which borders it on the west, north, and east), and the Coastal Plain upland (which borders it on the southeast and south). A few ridges along the southeastern side of the Sanford basin and in the northern part of the Durham basin rise to the level of the bordering uplands. This lowland is a rolling surface with a local relief of about 100 feet along the main streams. Regional slopes of different parts of the lowland are toward the nearest main streams. Terraces are present extensively at four levels along the Deep, Haw, and Cape Fear Rivers and their larger tributaries in the lowland.

Streams within the Triassic lowland are partly adjusted to the structure of the underlying rocks. In the Sanford basin, the Deep River closely follows the outcrop of the easily-eroded shale in the Cumnock formation. Many of its first-order tributaries follow cross faults or dikes, and many second-order tributaries follow the less resistant upturned Triassic strata, locally forming rectangular or trellis drainage patterns.

PIEDMONT UPLAND

The Piedmont Upland is a rolling surface with a relief that does not exceed 100 feet, except along the Triassic borders and near the main streams. The Deep, Haw, and Rocky Rivers are entrenched as much as 150 feet in the Piedmont Upland, and near these streams the Upland is cut by steep, narrow tributary valleys. This Upland surface extends westward from the Deep River basin (where it is 350 feet above sea level) to the foot of the Blue Ridge in western North Carolina (where it is more than 1,000 feet above sea level). East of the Deep River basin this surface passes beneath the Coastal Plain deposits and is exposed only where the Coastal Plain cover has been stripped off. Near the Deep River coal field the Piedmont Upland has a southeasterly slope averaging about 10 feet per mile. Scattered monadnocks, northwest of the basin, rise several hundred feet above the Piedmont surface; monadnocks nearest the mapped area are Beck Mountain, 10 miles northwest of Carbonton, and Round Top Mountain, 10 miles north of Cumnock.

Most of the streams in the Piedmont Upland are not adjusted to the structure of the underlying rocks. Both the Haw River and the Deep River above High Falls maintain remarkably straight courses across diverse types of rock. In their lower courses, these rivers enter

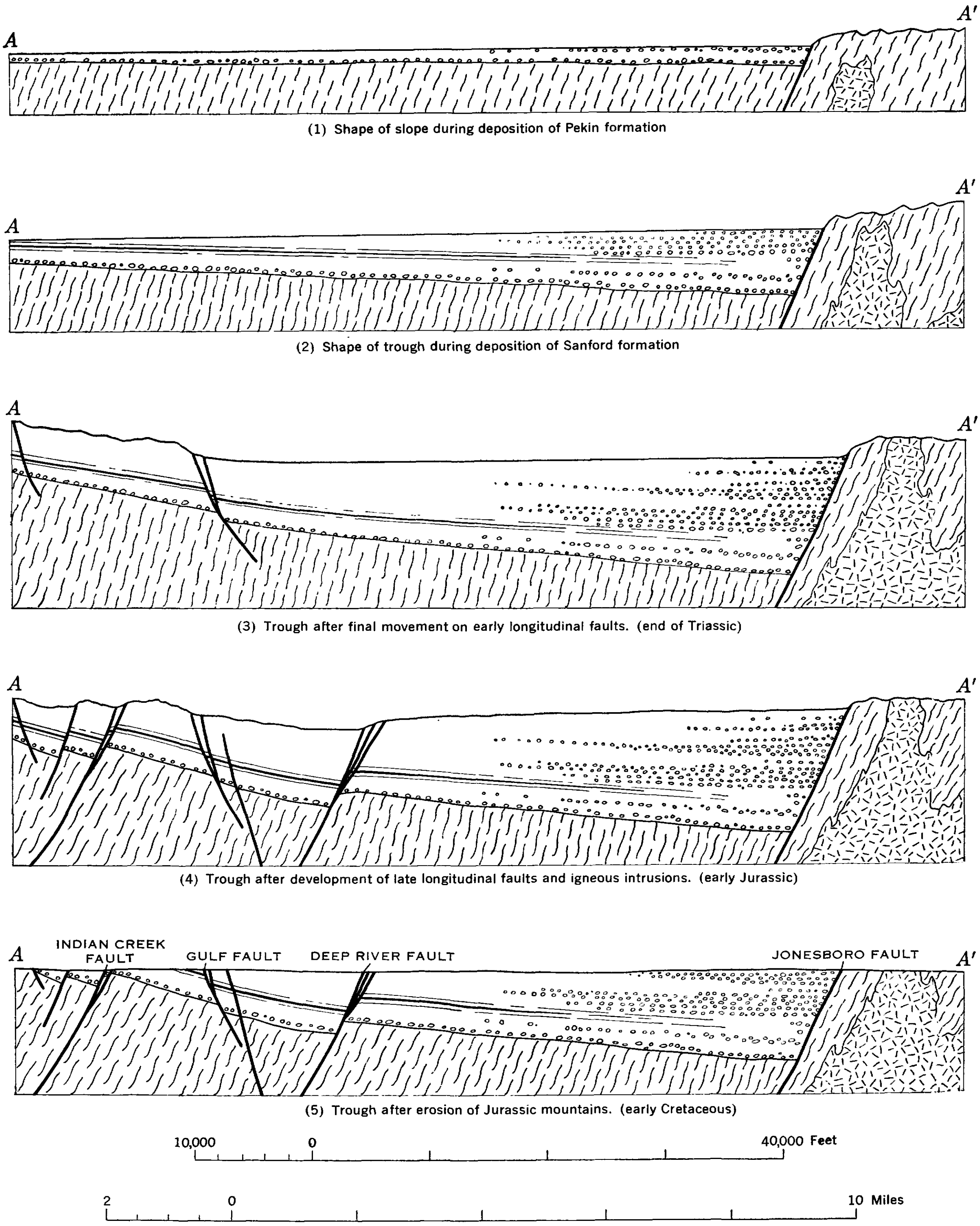


FIGURE 35.—Theoretical sections showing development of Deep River Triassic basin along line of section A—A′, plate 2.

the Triassic lowland, then leave it again before reentering the lowland near Moncure, thereby failing to consistently utilize the less-resistant strata of the Triassic belt. Tributary streams in the Piedmont Upland generally form dendritic drainage patterns that show little effect of the northeast-trending outcrop and cleavage of the underlying rocks.

COASTAL PLAIN UPLAND

The Coastal Plain upland along the southeastern side of the Deep River coal field is as much as 200 feet higher than the Triassic lowland and as much as 100 feet higher than the Piedmont Upland on the northwestern side of the field. The highest elevations in the mapped area are along the inner edge of the Coastal Plain.

This upland surface is gently rolling with smooth rounded divides and flat-bottomed valleys. It has a regional slope toward the southeast, but this is not as regular as the regional slope of the Piedmont Upland. East of the Deep River basin the Coastal Plain descends to the ocean in a series of marine terraces.

Within the mapped area the Coastal Plain deposits are poorly consolidated and differ little in resistance to erosion from one place to another. The streams form dendritic drainage patterns that probably reflect initial irregularities in the landscape. Locally, the streams have cut through the Coastal Plain cover and are superposed on the underlying Triassic and pre-Triassic rocks.

FALL LINE

The boundary between the Piedmont plateau and the Coastal Plain is commonly called the "Fall Line" because streams that flow across this line have falls or rapids at or near it. In most places along this line the Piedmont plateau is higher than the adjacent Coastal Plain because of the greater resistance of the Piedmont crystalline rocks.

In central North Carolina the Fall Line does not have this characteristic topographic expression. The Cape Fear River and other rivers flow on crystalline rocks for several miles after they enter the Coastal Plain, consequently they have falls and rapids for long distances below, as well as above, the Fall Line. Where it is bordered by the Deep River basin the Fall Line is a prominent northwest-facing scarp and the Coastal Plain is higher than the Piedmont. Northeast and southwest of the mapped area this line is not a prominent topographic feature.

INTERPRETATION OF GEOMORPHIC FEATURES

PIEDMONT PENEPLAIN

Geomorphologists regard the Piedmont Upland as a peneplain (a surface of degradation developed by baseleveling of the pre-existing hills or mountains during a long period of crustal stability). This peneplain truncates the Triassic sediments and structures, therefore it is a post-Triassic development; it passes beneath the Pliocene (?) high-level surficial deposits along the inner edge of the Coastal Plain, and therefore it antedates these deposits.

The relationship of the Piedmont peneplain to the Tuscaloosa formation of Cretaceous age, which crops out a few miles southeast of the mapped area, is not clear. It may truncate the Tuscaloosa beds, thus forming the erosion surface, noted by Stephenson (1912, p. 264–265), that separates the Tuscaloosa from the overlying Pliocene (?) high-level deposits. If this is the correct interpretation, then the Piedmont peneplain is partly, or wholly, post-Cretaceous. On the other hand, this peneplain may pass beneath the Tuscaloosa beds; it may be the same pre-Cretaceous peneplain that forms the surface of the crystalline rocks beneath the western part of the Coastal Plain.

To determine which interpretation is correct, it will be necessary to map the contacts of the Cretaceous beds, the Pliocene (?) high-level deposits, and the pre-Triassic rocks on a topographic base in order that accurate profiles of these contacts may be constructed and compared with profiles of the Piedmont west of the Deep River basin. According to Prouty (1946), the slope of the peneplain beneath the western part of the North Carolina Coastal Plain averages about 14 feet per mile; this is only slightly less than the average slope of the Piedmont Upland near the Deep River basin.

It is certain that a peneplain existed in the Deep River coal field, and over the Piedmont plateau generally, before the Cretaceous Coastal Plain formations were deposited. It is also certain that these Cretaceous beds were extensively eroded and that a peneplain was again developed before the Pliocene (?) high-level deposits were laid down, unless these high-level deposits are dominantly of Cretaceous age. Whether the present Piedmont peneplain (from which the high-level deposits have been partially stripped) is the same peneplain that existed in this region when the Cretaceous formations were deposited, or whether it represents a lower and younger peneplain (cut at a slight angle with the pre-Cretaceous peneplain after regional tilting), is a subject for a regional study beyond the scope of this report.

DRAINAGE PATTERNS

The Coastal Plain formations originally extended some distance west of the present Fall Line. It has long been assumed that the streams of the Piedmont plateau originated on the surface of a cover of Coastal Plain deposits, that these streams were superposed on the Piedmont crystalline rocks as this cover was eroded, and that the present poor adjustment of most Piedmont streams to the underlying rocks is a result of this superposition. This hypothesis is the simplest explanation for most of the poorly adjusted drainage in the Piedmont Upland near the Deep River coal field.

The Deep River basin was probably covered by the Cretaceous Coastal Plain formations, and after these had been stripped off it was again covered by the Pliocene (?) high-level deposits. The Cape Fear, Haw, and Deep Rivers probably developed as consequent streams on the Cretaceous cover. They had been superposed onto the Triassic and pre-Triassic rocks, and they had approximately their present courses when the high-level deposits were laid down. Deposition of the Pliocene (?) high-level sand and gravel apparently did not cause important dislocations in the river channels (although the channels were temporarily filled), but it probably caused extensive changes in the smaller streams. It is probable that many tributaries in the Piedmont Upland were superposed from the cover of high-level surficial deposits, just as the streams southeast of the Deep River field are now being superposed from this cover.

Since the removal of the Coastal Plain deposits, erosion of the relatively less-resistant Triassic rocks has been more rapid than erosion of the bordering pre-Triassic rocks. Consequently, the surface of the Triassic belt has been reduced to a lowland, and the superposed streams within that belt have partly adjusted themselves to structure by etching-out easily eroded strata, joints, and faults. Streams in the Triassic lowland are somewhat better adjusted than those in the Piedmont Upland, but this adjustment is far from complete.

In its lower course the Deep River flows northeastward, roughly perpendicular to the southeastward courses of the Cape Fear, the Haw, and other rivers in central North Carolina, and also perpendicular to the regional slope of the Piedmont plateau. Its upper course is southeastward and parallel with adjacent rivers. The change from a southeasterly to a northeasterly direction of flow takes place abruptly a short distance above High Falls (see fig. 4).

This unusual behavior of the Deep River may be a result of stream piracy. Originally, the Deep River may have continued southeastward to the ocean instead of turning abruptly eastward to join the Cape Fear River. A tributary of the Cape Fear River, advancing headward toward the southwest, could have tapped the ancestral Deep River near High Falls and diverted it eastward. This piracy could have occurred on the Cretaceous Coastal Plain cover, the headward advance of the tributary having been facilitated by a belt of weak rock in the Coastal Plain sediments, or it may have occurred after these sediments were stripped off, the tributary developing along the Deep River fault and advancing headward in the Triassic belt. If stream piracy is responsible for the peculiar course of Deep River, the abandoned ancestral channel should be partly preserved beneath post-Cretaceous deposits southwest of the mapped area.

TERRACES

Terraces and terrace deposits are distributed extensively along the main streams in the Triassic lowland. The distribution of these terraces has already been discussed in the chapter on post-Triassic deposits; the terrace profiles are shown in figure 4. These terraces are at four levels designated Terrace No. 1, Terrace No. 2, Terrace No. 3, and Terrace No. 4, in order of increasing altitude above the river. The range of average altitudes of these terraces is as follows:

Terrace No.	Range of average elevation above sea level within mapped area (in feet)	Range of average elevation above river level within mapped area (in feet)
1	170–185 (below Moncure only)	20–25
2	185–260	15–45
3	230–285	50–75
4	290–330 (above Carolina mine only)	90–110

These terraces represent four episodes of stream aggradation and valley filling, separated by intervals of renewed downcutting with removal of part of the previously deposited fill. The episodes of aggradation may be correlated with rises in sea level, which are believed to have occurred during Pleistocene interglacial stages; the intervals of downcutting may be correlated with a lowering of sea level during stages of Pleistocene continental glaciation. The distribution of these terraces mainly within the Triassic belt shows that this belt was a topographic lowland when the terraces were formed. A comparison of basal contacts of the terrace deposits shows that river channels within the mapped area have been lowered not more than 50 to 75 feet since the terrace development began.

The correlation of the river terraces in the Deep River region with the Pleistocene marine terraces of the Coastal Plain has not been established. The Coharie terrace, which is the highest marine terrace mapped by Stephenson (1912, p. 273–277) in the North Carolina Coastal Plain, extends along the Cape Fear River as far upstream as Lillington, about 14 miles below Buckhorn Dam. Precise altitudes of marine terraces in North Carolina are not known, but the shore line of the Coharie terrace in South Carolina is 215 feet above sea level, according to Cooke (1936, p. 6). If the profiles of the three river terraces near Buckhorn Dam are projected downstream, the approximate altitudes of these terraces at Lillington would be as follows: Terrace No. 1, 155 feet; Terrace No. 2, 170 feet; Terrace No. 3, 205 feet.

Allowing for errors in projecting the profiles and for differences in altitudes of shore lines in North and South Carolina, Terrace No. 3 correlates approximately with the Coharie terrace at Lillington. Terrace No. 2 and Terrace No. 1 may correlate respectively with the lower Sunderland and Wicomico marine terraces farther downstream, and Terrace No. 4 may correlate with the Brandywine terrace mapped by Cooke above the Coharie terrace in South Carolina. This correlation is no more than a suggestion, however. It is not possible to definitely establish the relationship between the Pleistocene marine terraces of the Coastal Plain and the river terraces of the Deep River basin until the altitudes of the marine terraces in North Carolina have been determined and the terrace profiles along the entire Cape Fear River have been studied.

GEOMORPHIC HISTORY

Post-depositional deformation of the Deep River Triassic basin at the end of the Triassic, or during the early Jurassic, was accompanied by widespread structural disturbances that produced a hilly or mountainous landscape in the Atlantic coastal region. The Triassic drainage lines were destroyed, a system of through-flowing streams was established, and a long period of erosion began. During the late Jurassic and early Cretaceous there were no important structural disturbances. The mountainous landscape was gradually eroded to a peneplain that cut across both the Triassic sedimentary rocks and the pre-Triassic igneous and metamorphic rocks. In early Cretaceous time the Deep River Triassic basin had essentially its present extent, but the landscape of the region probably was less rugged than at present.

The later Cretaceous and Tertiary history of central North Carolina is recorded in the Coastal Plain formations southeast of the Deep River region and is described in detail by Clark, Miller, and Stephenson (1912). Uplift of the Appalachian region to the west was accompanied by eastward tilting of the early Cretaceous peneplain and by an invasion of the sea in eastern North Carolina. The peneplain was covered during later Cretaceous time by debris eroded from the uplifted Appalachian region and deposited partly beneath the sea and partly on the continental margin. Some of these Cretaceous deposits probably covered the Deep River basin. Several uplifts and depressions of central North Carolina, relative to sea level, occurred during the late Cretaceous and Tertiary; periods of stream erosion probably alternated with periods of stream aggradation in the Deep River region as the rivers adjusted their gradients to the changes in sea level, to uplifting of the source area, or to warping of the Coastal Plain. Erosion generally dominated deposition during the Tertiary; by Pliocene time the older Coastal Plain deposits (which may have covered the Deep River basin) had been stripped off, the basin itself was a topographic lowland, the major drainage lines had been established, and the general topography of the Deep River region was much like it is today.

Because of a rise in sea level, an uplift of the source area, or a climatic change that affected the carrying capacity of the streams, an alluvial mantle of sand and gravel was spread over the Deep River region, probably during the Pliocene. Erosion of this mantle began as the sea level was lowered during the first advance of the continental ice sheets early in the Pleistocene. During the Pleistocene, the interglacial stages were episodes of valley filling as the streams flowing through the Triassic lowland sought to adjust their gradients to the rise of sea level; the glacial stages were episodes of downcutting when part of the previous fill was removed and the valleys were cut deeper. Streams in the Deep River coal field are now deepening their channels, clearing away the Pleistocene valley fills, and attacking the remnants of the Pliocene (?) mantle.

ECONOMIC GEOLOGY

COAL

MINING DEVELOPMENT

HISTORY OF MINING

Coal was discovered in the Deep River region at about the time of the Revolutionary War. According to the best available information, it was first found in 1775 near Gulf, on land owned by George Wilcox. Eavenson (1942, p. 324) has summarized the circumstances of this discovery as follows:

> Wilcox had established a forge and bloomery on the Deep River in Chatham County in 1755, and it was proposed to make cannon and munitions there. On July 3, 1776 James Milles wrote to the Council of Safety as follows:
>
> "I must now inform you that on the North side of Deep River, and I believe not above a half mile from the Forge, there is Pit Coal and from what appears on the surface, such as is very good, so that there is sufficient reason to believe, were it dug for, great quantities might be Raised." [7]
>
> No further notice of this coal deposit appears until 1811, when mention of it was made in the Raleigh Star, with a list of mines and quarries in the state. A letter to the editors, dated July 18, 1811, said,
>
> "You have already noticed a Bed of Coal on Deep River in this County. The mine is in my neighborhood. The coal is very easily raised, appears to be plenty and is said to be of excellent quality. I have known three European Blacksmiths who have worked it * * * each of whom I have heard pronounce it as good Coal as they ever used in their respective native countries, and each of them preferred using it to charcoal." [8]
>
> The writer stated that cannon balls and shot were cast at the furnace during part of the Revolution.

Despite this early discovery, the existence of coal in the Deep River area was not widely recognized for many years. In 1820, Denison Olmsted (1820), professor of geology at the college in Chapel Hill, was apparently

[7] Quoted from: North Carolina Colonial Records, 1775–1776, v. 10, p. 647–650, 993.

[8] Quoted from: Ms. letter from Ch. McKenzie, in Thos. Henderson Letter Book, 1810–1811, p. 24. In North Carolina Hist. Comm. Library.

still unaware of the earlier mining at Gulf, because he wrote:

An extensive secondary formation has lately been discovered very near us. On the road between this place and Raleigh, travelling eastward, we come to it four miles from the College; * * * It is a sandstone formation. The varieties are red and grey * * *.

It was natural to look for coal here, and I have for some time directed the attention of my pupils, and of stone cutters to this object. Two or three days since one of the latter brought me a handful of coal, found in this range, on Deep River, in Chatham County, about twenty miles south of this place. The coal is highly bituminous, and burns with a very clear and bright flame. It is reported that a sufficient quantity has already been found to afford an ample supply for the blacksmiths in the neighborhood.

By 1824, however, Olmsted (1824, p. 5) had learned of the earlier coal discoveries at Gulf, because he wrote the following in the first geological report on North Carolina:

* * * a bed of considerable extent has been opened not far from the Gulf on Deep River.

It is about 50 years since this coal bed was first discovered. Mr. Wilcox, an enterprising gentleman, proprietor of the Old Iron Works at the Gulf, took some pains to have it opened, and to introduce the coal into use.

Emmons (1852, p. 131) noted the early mine development at Gulf, which he calls the "Horton mine" in his report of 1852, as follows:

* * * It was known in the revolution, and a report made to Congress, respecting it, is still extant. * * *

From 1825 to 1850, coal was discovered and mined at other places along the coal outcrop. Campbell and Kimball (1923, p. 14) refer to mining activity near Cumnock in 1830 as follows:

It is also probable that within the next 50 years after the Horton mine was opened the outcrop of the coal bed had been prospected and was fairly well known from Farmville [now the Carolina coal mine] at least as far as Gulf. Peter Evans, who owned the plantation in the great northward bend of Deep River, including the village now known as Cumnock, began mining coal, it is reported, on his property, then called Egypt in 1830.

Eavenson (1942, p. 325) noted the reported occurrence of coal on the Tyson plantation, which was in Moore County, south of Carbonton and northeast of the present Gardner mine, in a quotation of 1841 from the Fayetteville Observer:

Josiah Tyson, Esq. has presented us with a specimen of coal taken from the mine on his lands on Deep River in Moore County, of superior quality to any we have seen south of Pennsylvania. Indeed it is very similar to the Anthracite coal of that State. There is an inexhaustible supply of it.[9]

Other sources consulted by Eavenson show that in June 1842 Elisha Mitchell, geologist from Chapel Hill, inspected coal pits on the Farrish plantation, on the Houghton plantation near Gulf, and on George Wilcox's land.

Thus, it appears that by 1850 a great many prospects and small mines had been opened along the coal outcrop, and we may infer that a great deal was known in regard to the thickness and extent of the coal. This is confirmed by Emmons in his report of 1852, in which he describes the quality and thickness of coal beds in pits at Farmville, Taylor's, Gulf, Wilcox's (at site of present Gardner mine), and at Murchison's; this indicates that the coal outcrop was already well known from the present Carolina mine to the vicinity of Haw Branch.

Prior to 1850, coal was mined in the Deep River coal field on a small scale to supply local needs, but immediately after 1850 construction was started by a private company on a series of dams and locks to make the Deep River navigable and thus to provide a means of transporting Deep River coal to eastern and northern markets.

In anticipation of this new outlet, mining activity in the field was accelerated. At Farmville (now the Carolina mine), the Deep River Mining and Transportation Company (possibly the same company constructing the dams) began developing a mine. Eavenson (1942, p. 325) says of this project:

Some development work was done in 1850 and the shaft was completed in 1853 by the Deep River Company at Farmersville [Farmville], the intention being to haul the coal about a half mile to the river and ship it in barges of 100 to 200 tons capacity to Fayetteville, about 71 miles.[10]

A report by Johnson (1851) contains a map showing the locations of two shafts and eight pits on the Farmville and Homeville estates, and a dam and lock nearby on Deep River near the mouth of Buffalo Creek. At Egypt, too, development of a mine was reported by Campbell and Kimball (1923, p. 14):

In 1851 the Egypt plantation was sold to L. J. Houghton and Brooks Harris. Harris soon acquired the interest of Houghton, and in 1852 sank the Egypt shaft, probably the most important single piece of development work ever undertaken in this coal field. The shaft pierced the principal or Cumnock coal bed at a depth of 430 feet, but was continued to a total depth of 460 feet. The property changed hands frequently, and in 1854 passed into the ownership of the Governors Creek Steam Transportation and Mining Company, which operated the mine until after the Civil War when, by order of the Convention, the name was changed to The Egypt Company.

Additional exploration of the coal outcrop paralleled this activity at Farmville and Egypt, and Emmons (1856, p. 244–245) was able to report:

[9] Quoted in: Iron City and Pittsburg Weekly Chronicle, Feb. 26, 1841.

[10] Information based on report by: Johnson, W. R., Coal land of the Deep River Co. in North Carolina: Mining Mag., v. 1, p. 352 et seq., 1853.

The whole length of the outcrop, following its windings, is about thirty miles. The extreme point beyond Evander McIver's [site of present McIver mine] where the coal seams have been discovered, is at Martin Dyer's [near U. S. Highway 1 north of Sanford], where a boring cut a seam near the outcrop 10 inches thick. * * * The existence of coal seams has therefore, been determined by the auger, and by excavations from Martin Dyer's to Mr. Fooshee's, on the south side of the Deep River, in Moore County [near Glendon where Emmons says earlier] * * * the coal series is well developed, three or four seams of good coal having been exposed by several excavations directly over the outcrop of the seams * * *.

Meanwhile, the private attempts to complete a navigation system on Deep River had failed and the State took over the project. The Civil War broke out just as the construction of the locks and dams was completed, and shortly thereafter, because of neglect and floods, some of the dams were washed out. Only those at Lockville, Gorgas, and Gulf were maintained to supply waterpower for grist mills.

Because of the delay in obtaining slack-water navigation on Deep River, the construction of a railroad from Fayetteville to the coal field was started in 1855 at Fayetteville. According to the Sanford Herald (Sept. 16, 1948, p. 1):

The Western Railroad from Fayetteville reached Jonesboro in 1860, the first railroad in this entire section. The Civil War breaking out in 1861, the Western Railroad was at once extended by the Confederate government to near Egypt to get coal.

The end of this road was on the Scotch Ever McIver plantation some two miles this side of Egypt. To reach Egypt a deep cut would have been necessary and a bridge built over Buffalo Creek so the road was not built to the mine. Two dirt roads were used to haul coal to the rail head.

The government at once commenced to operate the mine on a very large scale, working night and day shifts * * *

Several mines in the Deep River field supplied coal for the Civil War, but apparently the total shipped was not large because Chance reported (1885, p. 23):

Some coal was shipped over this road from the shaft at Egypt, but the cost of transportation to Fayetteville and of trans-shipment and towing down the Cape Fear River to Wilmington (somewhat over a hundred miles, I believe), on a river full of shoals, was doubtless too great to leave any profit. Operations were most actively pushed in the period immediately preceding the war. During the war coal was mined at Farmville, Egypt, Gulf and the Evans' place [Black Diamond Mine], and shipped by river to Fayetteville and to Wilmington, where it was used to some extent by blockade-runners, but the aggregate amount thus shipped must have been quite small.

In the years following the Civil War the accessibility of markets for the Deep River coal was improved by the extension of the Western Railroad (now the Atlantic and Yadkin) to Gulf in 1879 and to Greensboro in 1884, by construction of the Raleigh and Western Airline Railroad (now the Seaboard Air Line Railroad), which reached Sanford in 1871, and by the completion of the Norfolk Southern Railway some years later. Navigation was revived on Deep River by the Deep River Navigation Company, which rebuilt and maintained a series of locks from Buckhorn to Carbonton. Iron ore was brought upstream from an iron mine near Buckhorn to the Endor iron furnace—then located on Deep River, south of Farmville. This was only a temporary arrangement, however, as indicated by Campbell and Kimball (1923, p. 15).

It is reported that slack-water navigation was carried on in 1873 and for several years thereafter, but eventually the locks and dams were permitted to fall into decay as the iron business declined and finally all were swept out of existence, and slack-water navigation on Deep River was a thing of the past.

Coal mining since the Civil War has centered in the mines shown on the geologic map (pl. 1). All these mines have operated intermittently and unsuccessfully because the complex system of faults and related diabase intrusives, which have displaced and metamorphosed the coal, have made mining impracticable. The history of each of these mines is summarized below.

Cumnock Mine.—The Egypt shaft, located about half a mile north of Cumnock and 1,000 feet south of Deep River, was put down by Brooks Harris between 1852 and 1854. As stated previously, this mine was sold in 1854 to the Governors Creek Steam Transportation and Mining Company, which operated the mine during the Civil War.

After the war, the Cumnock (then called Egypt) mine was operated by many different owners until it was closed in 1873. It remained closed and flooded until 1888. The property was then bought by William P. Henszey and Samuel A. Henszey and was reopened and operated as the Egypt Coal Company until 1905. Tuttle (1894) reported in 1894 that the output was less than 100 tons per day, although it was planned to boost production to 500 tons per day. This desired rate was not achieved, however, partly as a result of two explosions, one in 1895 and another in 1900, which killed 40 men. Woodworth (1902, p. 48) reported that a fire occurred in the mine in 1898. A report by Fulton (copy in McIntosh, 1944) in 1903 indicated that most of the mine was under water, that mining was being carried on in only part of the workings, and that production was 75 tons per day.

The Cumnock mine was closed and flooded from 1905 to 1915. It was then bought by the Norfolk Southern Railway, rehabilitated under the name of the Cumnock Coal Company, and operated by this company until 1922 to supply coal for the railroad. During these years, four holes were drilled to test the coal near the mine (holes DH 1, 2, 3, and 4, shown on pl. 1, and described in figure 8). In 1922, the mine was bought by the Erskine Ramsey Coal Company, which continued to supply coal to the railroad for several years. Geological and financial difficulties caused a steady decline in coal production, however. Finally, the mine was closed, and later it was flooded by the waters of Deep River.

The Carolina Coal Company bought the Cumnock property in 1927 and unwatered the mine to protect the workings of the nearby Carolina mine, which this company was then operating. In 1929, the mine was again flooded by the waters of Deep River, and it has never been reopened. After a series of disasters at the Carolina mine, the Carolina Coal Company failed, and both the Cumnock and Carolina properties were taken over by the Dial Estate in 1933. In 1946, these properties were bought by the present owner, Walter Bledsoe and Company.

Carolina Mine.—Mining at Farmville, now the site of the Carolina mine, 1½ miles east of Cumnock, began long before the Civil War. As already noted, the first major attempt to develop a mine at Farmville was by the Deep River Mining and Transportation Company in 1850. During the Civil War a small quantity of coal was produced there.

Apparently, operations at Farmville ceased after the war. The next recorded mining activity was in 1884, when Chance (1885, p. 26–35) opened some of the old pits and slopes to obtain information on the quality and thickness of the coal; at this time, 165 tons of coal was mined for use in the Raleigh State Exposition.

The present Carolina mine was not started until 1921. After preliminary drilling in the area, the Carolina Coal Company (composed originally of J. R. McQueen, Bion H. Butler, Howard N. Butler, and John Powell, of Southern Pines) opened the Carolina slope. For several years the development and operation of the mine were successful, and McQueen stated (personal communication) that the average production was about 200 tons per day. In 1929, however, an explosion killed 53 men in the mine and crippled the organization so severely that, when a runaway mine car killed several men in another accident the following year, the mine was forced to close. At about this time, Eavenson, Alford, and Hicks became interested in the Carolina mine and put down four holes to test the coal in the mine area (holes DHA–1, 2, 3, and 4, shown on pl. 1, and described in the Appendix). They could not reach a satisfactory agreement with the Carolina Coal Company, however, and in 1933, this property and the Cumnock mine were taken over by the Dial Estate.

The Carolina mine was leased and reopened in 1942 by a local organization known as Coal Products Incorporated. Part of the slope was rehabilitated, and an attempt was made to mine a pillar between the fourth and fifth left entries. This effort was abandoned in 1944 when the workings penetrated an area of broken and faulted coal. In 1946, this mine, the Cumnock mine, and other properties of the Dial Estate in the Deep River coal field were bought by Walter Bledsoe and Company. The Carolina mine was reopened by the Raleigh Mining Corporation in 1947.

McIvor Mine.—The existence of coal at the site of the McIvor mine, 2 miles southeast of Cumnock, was known at the time of Emmons' investigation. Campbell and Kimball (1923, p. 75) stated that coal was mined extensively there at about the time of the Civil War. They also reported that Charles Reaves, of Sanford, had briefly reopened the mine several years before their survey was made. The McIvor mine was leased and operated by O. A. Wakefield, of Sanford, in 1936, and by M. C. Reeves, of Pittsboro, in 1942 and 1943. This mine has not been reopened since that time.

Taylor Slope.—The Taylor slope, located 1 mile east of Gulf on the old Taylor property, is probably one of the oldest mines in the Deep River field. Coal from this slope was shipped to Fayetteville during the Civil War. A nearby slope on the Gulf property, now owned by R. B. Jordan of Gulf, was known at one time as the Gulf mine. Chance (1885, p. 37) reported that the slope was put down by Messrs. Dewees and Co. of Pottsville, Pa. about 1880, although the 1880 census (Tenth Census, p. 899) reported the only mine operating during that year, as follows: Gulf Mine: Operator, E. L. Houghton; product, 350 tons; thickness of coal, 6½ feet; Market, Raleigh, Charlotte, Fayetteville, and Lawrenceburg.

This may refer to a different mine, possibly to one of the many pits in and near Gulf (see pl. 1), or perhaps to a pit near the present Gulf mine. Chance reported that mining was being carried on at this place by a Mr. Williams in 1884. Jordan (personal communication) indicates that the last activity at this site was in 1902, when the slope on the Gulf property was operated by W. H. Hill and G. F. Cant for the North Carolina Coal and Coke Company.

Gulf Mine.—The slope to which the name "Gulf mine" is applied in this report is west of Gulf, also on land owned by R. B. Jordan. It is probable that the earliest mining references at Gulf pertain to pits in this vicinity. This particular opening, however, was started during the Civil War, according to Jordan (personal communication). The slope was reopened and extended by C. H. Gunter, during 1924–2? (see fig. 32). Jordan opened an adjoining slope in 1926. Gunter shipped coal to the University of North Carolina and to the Jefferson-Standard building in Greensboro; Jordan sold his entire production to the brickyard near Gulf.

Deep River Mine.—The Deep River mine, 2 miles west of Gulf, was first opened by C. H. Gunter in 1932 and was operated until 1936. It has been closed since that time.

Black Diamond Mine.—The Black Diamond mine was listed by Chance (1885, p. 43) as the "slope at the Evans place," and it has also been called the Carbonton mine. It is located on the south side of Indian Creek, 1½ miles northwest of Carbonton. Chance stated that this mine was worked during the Civil War, but little work has been done since then. O. A. Wakefield opened it briefly in 1931, and John M. McIvor, of Gulf, opened the mine for examination several years later.

Gardner Mine.—Although Campbell and Kimball reported that a prospect pit existed on the Gardner place (2 miles south of Carbonton) in 1923, apparently the first extensive development work was by McConnell and Phillips from 1931 to 1935. The coal was shipped to Darlington, S. C., where McConnell had a coal and ice business. John M. McIvor operated the mine for a short period after 1935, but it has been closed for more than a decade.

Murchison Mine.—According to quotations already presented, mining was carried on at the Murchison mine, near Haw Branch, during the Civil War (probably on a very small scale). The next important period of activity was from 1931 to 1936, when this property was leased and operated by O. A. Wakefield of Sanford. According to A. J. Wakefield (personal communication), the mine was financially successful during this time. Coal was supplied regularly to Lee and Moore County schools and to hotels and hospitals in Southern Pines and Pinehurst. The mine was closed in 1936, because the owners wanted to sell the property and refused to extend the lease. It has not been reopened since that time.

Jones Coal Pit.—A group of coal pits are located southwest of the Murchison mine on land that originally was part of the Fooshee plantation (later known as the Jones place). Previous quotations from Emmons indicate some early prospecting there. Chance put in five shafts at this place and found very little coal; no subsequent work has been done. The largest and most conspicuous of the openings is labeled the "Jones coal pit" on the geologic map (pl. 1).

Other pits.—There are a great many pits in the vicinity of Gulf (see pl. 1). None of these seem to have been worked within the past 50 years. Most of them were developed before, and during, the Civil War, although Chance (1885, p. 40–42) reported that Messrs. Dewees and Co., of Pottsville, Pa., sank a new slope at Gulf about 1880 (at about the same time this company sank the Taylor slope, east of Gulf). He also stated that a number of holes were being drilled to test the coal southeast of Gulf in 1884, but apparently no logs of these holes are in existence.

An old shaft is located southeast of the McIvor mine and north of Sanford, but there is no historical information available. The dump beside this shaft contains gray and black shale, but no coal is visible. Campbell and Kimball (1923, p. 75) stated:

"There is a vague report current that this shaft is 400 feet deep, but it is now full of water and that rumor could not be verified."

Several pits have been opened on the thin coal bed north of Brickhaven (see pl. 1). Only one pit appears to be deep, and all are caved. Their histories are unknown to this writer.

Because of the recent growth of industry in central North Carolina, accompanied by an expansion in the local market for Deep River coal, there has been a renewed interest in the development of the coal resources of this field. The U. S. Bureau of Mines drilled six holes in the center of the field in 1944–45 and two more in 1947–48. Walter Bledsoe and Company drilled 11 holes to test the coal in 1945–46, and they purchased the Dial Estate, including the Carolina and Cumnock mines, in 1946. In 1947, the Raleigh Mining Company, a subsidiary of Walter Bledsoe and Company, reopened the Carolina mine. By 1950, this organization had reconditioned the slope, installed new equipment in the mine and was producing more than 100 tons of coal per day. Most of this coal was sold to the Carolina Power Company and was trucked from the mine to the steam power plant southeast of Moncure.

CONDITION AND EXTENT OF MINE WORKINGS

In 1950, the Carolina mine was the only mine operating and was the only one that was not caved or flooded, although extensive parts of the workings were inaccessible. Very little information as to the extent of the underground workings is now available for most of the mines; maps are in existence of only the Carolina and Cumnock mine workings (see pls. 5 and 6).

The following brief digest of information on surface conditions, extent of workings, and beds from which coal was extracted at the mines shown on the geologic map (pl. 1) has been prepared from the older reports, from field notes, and from discussions with mine operators and local residents in the Deep River coal field.

Cumnock Mine.—Two vertical shafts were used in operating the Cumnock mine. These shafts are located on the lower terrace (Terrace No. 2) along the south side of Deep River. The hoisting shaft is 2,000 feet southeast of the Cumnock Bridge. It is a 3-compartment shaft, 8 by 16 feet in cross section, and 464 feet deep, that cuts the top of the Cumnock coal bed at a depth of 430 feet below the surface. A ventilating shaft is located about 550 feet north of the hoisting shaft; it is 220 feet deep, and at one time it had a 20-foot ventilating fan. It was through this shaft that the mine was flooded by the waters of Deep River. Both shafts are caved, and no surface equipment or buildings remain.

The Cumnock mine workings cover an area approximately 1,500 by 2,000 feet on the west side of the main (hoisting) shaft, and 1,000 by 1,200 feet on the east side; these workings are shown on plate 5. Two diabase dikes cut the workings into three parts. Before 1918, almost all of the mining was done on the eastern side of the dike, which is near the main shaft; however, accurate maps of this part of the mine are not available. The later mining was done west of the dike, and more detailed maps of these workings were maintained. Mining was done by the room and pillar method.

All of the workings are in the Cumnock coal bed. The main bench of the Cumnock bed, the blackband below the main bench, and the lower benches of coal in this bed, making a total thickness of 7 to 7½ feet, were all mined during the earlier period of activity. In the later operations, only the main bench, 3½ to 4 feet thick, was extracted.

Carolina Mine.—The Carolina mine is operated through two slopes. The portals of these slopes are on the north side of Deep River near the edge of the upper terrace (Terrace No. 3) about 1½ miles east of Cumnock. The main (hoisting) slope starts about 150 feet south of the coal outcrop (above the coal bed) and has an average inclination of about 30° for the first 720 feet, where it meets the main bench of the Cumnock coal bed. At this point, which is about 360 feet below the surface, the slope flattens, and from there it closely follows the coal. This is a single track slope. The air slope and manway starts on the coal outcrop about 300 feet northwest of the main slope. It follows the coal bed for the first 300 feet, then it encounters a fault zone that drops the coal. The air shaft steepens in passing through this fault zone and again strikes the coal at a depth of about 300 feet below the surface on the other side of the zone. From this point, the air slope roughly follows the main bench of the Cumnock coal bed and parallels the main slope.

Surface equipment, buildings, track, tipple, crusher, and sizing equipment are new or rebuilt. The Raleigh Mining Company has also completely recorditioned the slopes; a steel-plate lining has been installed in all areas of intense faulting, and new timbers were used elsewhere.

The Carolina mine workings explore an area roughly 2,600 by 2,400 feet, extending westward under the Deep River. These workings are shown on plate 6. Since 1948, the Raleigh Mining Company has extended a branch slope (originally started in 1944 by Coal Products, Inc.), which starts from the main slope between the fourth and fifth left entries, and they have opened the workings in the extreme southeastern corner of the mine. Mining has been by the room and pillar method.

Nearly all of the production of the Carolina mine has come from the main bench of the Cumnock coal bed. The Gulf bed has been penetrated in two places (as shown on pl. 6) : in the air slope, and in the branch slope driven by Coal Products, Inc. (for a distance of about 400 feet). In both places, faulting has set the Gulf bed precisely against the main bench of the Cumnock coal bed.

McIvor Mine.—The McIvor mine was operated through a slope at the coal outcrop on the south bank of a branch of Pretty Creek. The buildings and equipment have been removed, the slope is caved, and the site is covered with a dense growth of young pine trees.

No maps are available showing the extent of the underground workings. The entire production came from the main bench of the Cumnock coal bed, which Arthur J. Wakefield reports (personal communication) ranged in thickness from 14 to 40 inches. The reported abrupt changes in coal thickness are probably a result of the faulting and intrusions in the vicinity of this mine (see pl. 1).

Taylor coal pit.—As previously stated, there are actually two adjacent slopes at the locality marked "Taylor coal pit" on plate 1. Although both are caved, the portals of these slopes were located in the forest a few hundred feet north of the west clay pit of the Chatham Brick and Tile Company, 1 mile east of Gulf. One of the slopes was in the Gulf coal bed, the other was in the Cumnock coal bed. Their relative positions are shown in figure 36, as modified from Chance (1885, p. 38).

Not more than a few hundred tons of coal were mined at this place, and the workings were not large, although the slopes exceeded 100 feet in depth. Chance reported that the coal was cut off by a fault west of the slope on the Taylor property, and consequently the workings did not extend far in that direction. Probably this was the same fault mapped in the nearby clay pit shown on plate 1. In these workings, the main bench of the Cumnock coal bed was reported to be 3 feet thick, and the Gulf coal bed was reported to be 2 to 2½ feet thick.

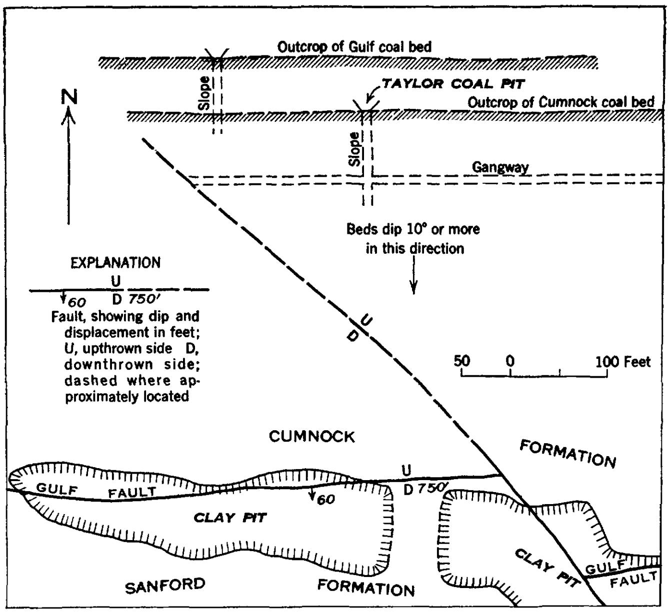


FIGURE 36.—Mine workings at Taylor coal pit, 1 mile east of Gulf. Shows relationship of Taylor coal pit to Gulf fault and clay pits of Chatham Brick and Tile Co.

Gulf Mine.—The Gulf mine, located 100 feet south of the road from Gulf to Carbonton, has two slopes and two sets of workings (see fig. 32). One slope is oblique to the strike of the coal, the other is perpendicular to it. Both are in the main bench of the Cumnock coal bed. Although both slopes are caved, this coal bed is well exposed at the portals, where it is 40 inches thick. Jordan (personal communication) estimated that about 1,000 tons of coal were mined here, but no accurate map of the workings is available. The coal bed in this area is offset by many faults associated with the Gulf fault zone; many such faults were encountered in this mine.

Deep River Mine.—There is no information available as to the extent of the workings at the Deep River mine, located 600 feet south of the road from Gulf to Carbonton. A large dump, containing shale with fragments of anthracite, suggests that the workings must be extensive, but the slope is caved and inaccessible. A large building, which contains grinding equipment and a rotary drier, is still standing. The production of this mine was from the main bench of the Cumnock coal bed, which is reported to have averaged 26 inches in thickness.

Black Diamond Mine.—The old Black Diamond mine is in a heavily forested area along the south side of Indian Creek about 400 feet south of the road from Gulf to Carbonton. The workings consist of an old slope (now caved), a shaft, and an airway; all these are connected by a gangway that joins the slope at a slant depth of about 93 feet. The airway was open in 1949, but it was flooded to within 10 feet of the portal. There are a great many surface prospect pits in the vicinity. Both the Gulf and the Cumnock coal beds are exposed on a nearby cliff along Indian Creek.

Chance reported that all of the workings in the Black Diamond mine were in the lower of two benches of coal in the Cumnock coal bed. The bench that was mined ranged in thickness from 18 to 32 inches, according to Chance. This is probably the same as the main bench of the Cumnock coal bed farther east, and the top bench here is a bench that is present only in the western part of the coal field.

Gardner Mine.—The Gardner mine, located on the west bank of a small creek, 2 miles south of Carbonton, was operated through a slope that extended to a slant depth of 300 feet, according to McIvor. This slope is caved, but a nearby air shaft that penetrates the edge of a terrace deposit is only partly blocked. A small dump of coal and shale remains at the mine, but there are no buildings or equipment. No map is available of the workings; however, the mine is known to have been rather small.

The coal was mined from the upper of two benches in the Cumnock coal bed. This bench is 11 inches thick. Probably the lower bench here is equivalent to the main bench of the Cumnock coal bed farther east.

Murchison Mine.—Located less than half a mile west of Haw Branch on the south bank of a ravine, the Murchison mine is marked by a large dump of coal and coaly shale. Buildings and equipment have been removed. There are two slopes, both caved; one slope served as an air course, the other was used for haulage. Mining was done on the lower of two benches of coal, here correlated with the main bench of the Cumnock coal bed. This bench ranged from 36 to 42 inches in thickness according to Wakefield, but it was shaly. An exposure of this bench at the portal of one slope is 36 inches thick.

PRODUCTION

There have been three important periods of coal production, separated by intervals of little, or no, mining activity, in the history of the Deep River coal field. The first of these periods was from 1861 to 1873, when a number of mines were active because of stimulus provided by the Civil War. The second period was from 1889 to 1905, when the Cumnock mine was the only producer. The third period was from 1918 to 1930 (the period of greatest production in the history of the field), when both the Cumnock mine and the Carolina mine were active.

Records of coal production are very incomplete for the years prior to 1890. There is no record of production during, and immediately following, the Revolutionary War, but it is unlikely that more than a few hundred tons were mined during this time. The first recorded production was in 1840, when 3 tons were mined. Within the succeeding 50 years, only incomplete production figures are available, although Eavenson (1942, p. 550) has made estimates for some years for which no published figures exist.

Published records of tonnage and value of coal produced, number of miners, and number of days of mining activity, are fairly complete for the period from 1890 to 1935. These figures are listed below, together with estimates of production for the years from 1936 to 1948, based on statements of mine operators.

TABLE 8.—*Tonnage and value of coal produced, working days, and manpower of mines, Deep River coal field, 1890–1948* [1]

Year	Coal production (short tons)				Total value of product	Average number of working days	Average number of employees
	Loaded at mines for shipment	Sold to local trade	Used at mines	Total production			
1890	-----	-----	-----	10,262	$17,864	-----	-----
1891	18,780	600	975	20,355	39,635	254	80
1892	6,679	-----	-----	6,679	9,599	160	90
1893	15,000	-----	2,000	17,000	25,500	80	70
1894	13,500	1,000	2,400	16,900	29,675	145	95
1895	23,400	600	900	24,900	41,350	226	61
1896	5,356	295	2,162	7,813	11,720	220	18
1897	21,280	-----	-----	21,280	27,000	215	51
1898	9,852	304	1,339	11,495	14,368	-----	-----
1899	24,126	486	2,284	26,896	34,965	210	70
1900	14,757	492	2,485	17,734	23,447	151	84
1901	10,000	-----	2,000	12,000	15,000	300	25
1902	20,400	100	2,500	23,000	34,500	285	40
1903	14,429	87	2,793	17,309	25,300	264	49
1904	4,600	300	2,100	7,000	10,500	240	25
1905	461	1,096	-----	1,557	2,336	60	15
1906	-----	-----	-----	-----	-----	-----	-----
1907	-----	-----	-----	-----	-----	-----	-----
1908	-----	-----	-----	-----	-----	-----	-----
1909	-----	-----	-----	-----	-----	-----	-----
1910	-----	-----	-----	-----	-----	-----	-----
1911	-----	-----	-----	120	-----	-----	-----
1912	-----	-----	-----	-----	-----	-----	-----
1913	-----	-----	-----	-----	-----	-----	-----
1914	-----	-----	-----	-----	-----	-----	-----
1915	-----	-----	-----	-----	-----	-----	-----
1916	-----	-----	-----	-----	-----	-----	-----
1917	-----	-----	-----	-----	-----	-----	-----
1918	466	42	912	1,420	6,745	40	50
1919	3,229	387	3,373	6,989	27,000	100	49
1920	8,660	-----	2,880	11,540	81,000	288	50
1921	20,000	-----	3,438	23,438	135,000	300	60
1922	68,524	1,500	8,546	78,570	388,000	167	127
1923	29,419	1,700	4,900	36,019	132,000	275	150
1924	51,094	1,200	4,800	57,094	224,000	287	120
1925	58,160	524	6,469	65,153	283,000	272	140
1926	51,997	1,485	4,457	57,939	243,000	292	155
1927	48,535	4,842	-----	53,377	191,000	284	140
1928	51,740	5,900	3,220	60,860	201,000	180	240
1929	46,280	3,200	2,700	52,180	177,000	260	160
1930	24,464	1,276	2,760	28,500	100,000	290	70
1931	-----	-----	-----	2,363	9,000	-----	-----
1932	-----	-----	-----	1,900	6,000	-----	-----
1933	-----	-----	-----	2,014	7,000	-----	-----
1934	-----	-----	-----	3,140	9,000	-----	-----
1935	-----	-----	-----	[2] 2,000	[2] 4,500	-----	-----
1936	-----	-----	-----	[2] 2,000	-----	-----	-----
1937	-----	-----	-----	-----	-----	-----	-----
1938	-----	-----	-----	-----	-----	-----	-----
1939	-----	-----	-----	-----	-----	-----	-----
1940	-----	-----	-----	-----	-----	-----	-----
1941	-----	-----	-----	-----	-----	-----	-----
1942	-----	-----	-----	[2] 3,000	-----	-----	-----
1943	-----	-----	-----	[2] 5,000	-----	-----	-----
1944	-----	-----	-----	[2] 3,000	-----	-----	-----
1945	-----	-----	-----	-----	-----	-----	-----
1946	-----	-----	-----	-----	-----	-----	-----
1947	-----	-----	-----	-----	-----	-----	-----
1948	-----	-----	-----	[2] 150	-----	-----	-----

[1] May include a few thousand tons from Dan River coal field.
[2] Estimate. See figure 37 for sources of data.

All of the published production figures, together with the publications where they appear, are listed in figure 37. The total production of the Deep River field from 1840 to 1949, based on these figures, is 1,051,088 short tons. This may include a few thousand tons produced in the Dan River coal field, inasmuch as the production of the two fields has not been separated in the records. The Dan River production, however, is almost negligible.

It is difficult to compute production estimates for the various mines in the Deep River field or to distribute the total production among them, inasmuch as individual mine records are not available, and accurate mine maps have not been maintained. Comparison of the production statistics for the period 1890 to 1948, listed above with the histories of the mines, suggests that the total production of the field since 1890, amounting to about 800,000 short tons, was contributed approximately as follows:

	Short tons
Cumnock mine	575,000
Carolina mine	200,000
Deep River mine	10,000
McIvor mine	6,000
Murchison mine	5,000
Gardner mine	3,000
Gulf mine	1,000

Based upon existing mine maps and what is known of the extent of mine workings in the field, the above figures are liberal, but not impossible, estimates of the total production of these mines. However, these figures do not account for more than 200,000 tons of reported production prior to 1890, which must have come from these same mines, together with the Taylor pits, the pits near Gulf, and the Black Diamond mine. The combined production of the Black Diamond mine, the pits near Gulf, the Taylor pits, and all other minor pits (not listed above) did not exceed 15,000 or 20,000 tons according to the best available estimates. Therefore we must conclude either (1) that the mined-out areas in this field resulting from mining done during the Civil War are considerably larger than has been realized, or (2) that these early production figures are in error.

EXTENT AND THICKNESS OF COAL BEDS

GENERAL DESCRIPTION

A brief description of the two coal beds in the Deep River coal field has already been presented in the chapter on the Triassic sedimentary rocks. It seems desirable to describe these beds in greater detail, however, in order to establish more clearly the relationships between thickness, quality, mining conditions, and reserves of coal in different parts of the field.

The Cumnock coal bed is the thickest and the most extensive of the beds in the Deep River field, and it has yielded all but a few hundred tons of the total production of this field. The Gulf coal bed is 28 to 40 feet below the Cumnock bed, and it is of minable thickness over a much smaller area. Both beds are in the lower part of the Cumnock formation, as shown in figure 6.

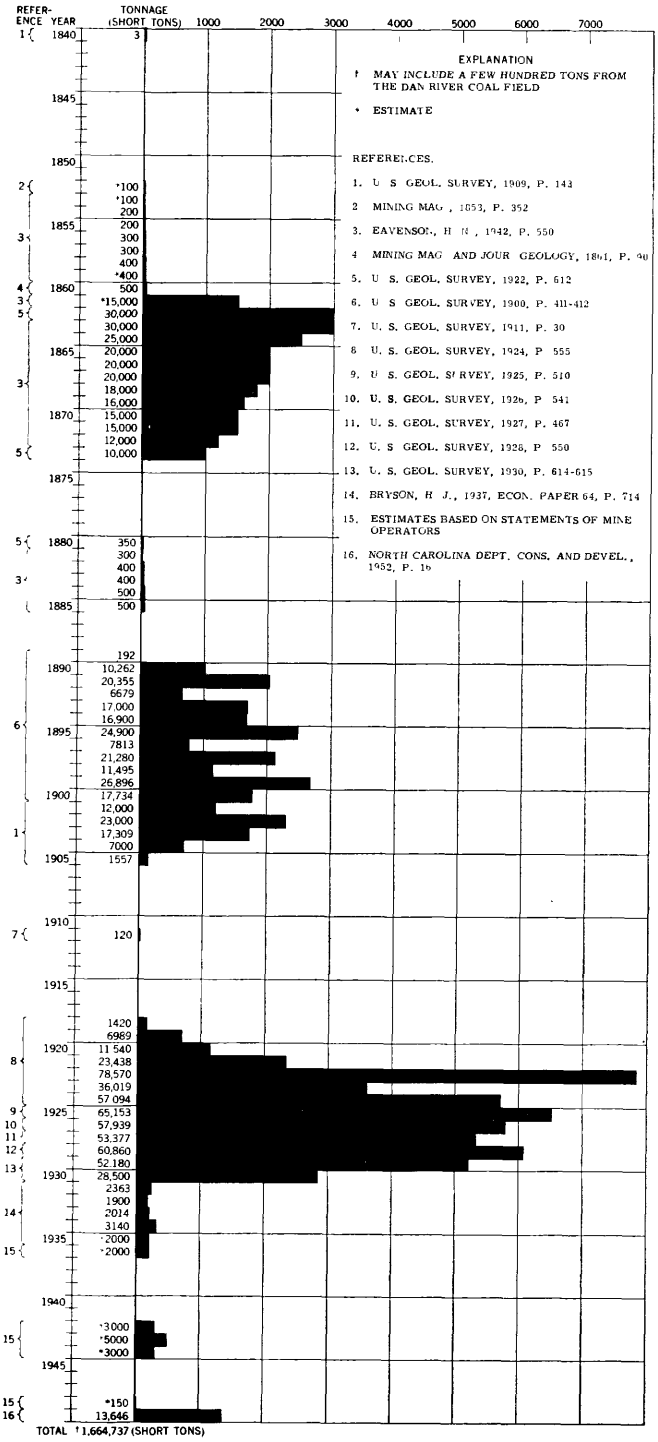


FIGURE 37.—Published records and estimates of coal production in the Deep River coal field, 1840–1949.

The Cumnock coal bed underlies an elliptical area of approximately 75 square miles in the northeastern part of the Sanford basin, as shown in figure 38. Except for interruptions caused by faulting and intrusions, this bed extends continuously from the vicinity of U. S. Highway 1, north of Sanford, to the Jones coal pit near Glendon (an airline distance of 12½ miles). It is thickest in the northern part of the field, between Gulf and the Carolina mine, becomes thinner and increasingly shaly toward the southeast, south, and southwest, and finally passes into shale, siltstone, and sandstone. A thin bed of coal, tentatively correlated with the Cumnock coal bed, is present in the southern part of the Durham basin (see pls. 1 and 4).

The Gulf coal bed occupies an area of about 22 square miles in the northeastern part of the Sanford basin (see fig. 38). It extends continuously from the Black Diamond mine to the Carolina mine (except where it is cut by faults or intrusions), but it has not been observed southeast, south, or southwest of that area.

COAL NORTH OF THE DEEP RIVER FAULT

GENERAL DISTRIBUTION AND THICKNESS

Within the 26 square mile area between the Deep River fault and the coal outcrop north of that fault, lies the thickest and highest quality coal in the Deep River coal field. Over much of this area the Cumnock coal bed consists of a main bench, overlain by a thinner, less continuous top bench, and underlain by one or two lower benches. The Gulf coal bed generally consists of a single bench, but in a few places it also contains a lower bench not more than a few inches thick. Detailed descriptions of these coal beds are given in the logs of test holes listed at the end of this report. Typical relationships between the top bench, main bench, and lower benches in the Cumnock coal bed are shown in the log of BMDH D–2. Sections of the Cumnock and Gulf coal beds measured in the main slope of the Carolina mine are described below.

Section of Cumnock coal bed in main slope of Carolina mine, 1,000 feet from portal

[About 100 feet down slope from section *D*, shown on pl. 6]

	Feet	Inches
Siltstone, medium gray (N5), locally carbonaceous	1+	
Claystone, medium dark-gray (N4)		6
Coal, bony, dull, cleats more than an inch apart		[1]2
Coal, faintly banded, bright, cleats less than an inch apart	2	[1]8
Coal, bony, dull, cleats more than an inch apart		[1]3
Shale, black, carbonaceous, ferruginous (Blackband)		2
Siltstone, medium gray (N5)		2
Shale, black, carbonaceous, ferruginous (Blackband)		5
Siltstone, medium gray (N5)	1	4
Coal, shaly, bony, dull, few cleats	1	[2]0
Claystone, medium dark-gray (N4), soft		2+

[1] Main bench.
[2] Lower bench.

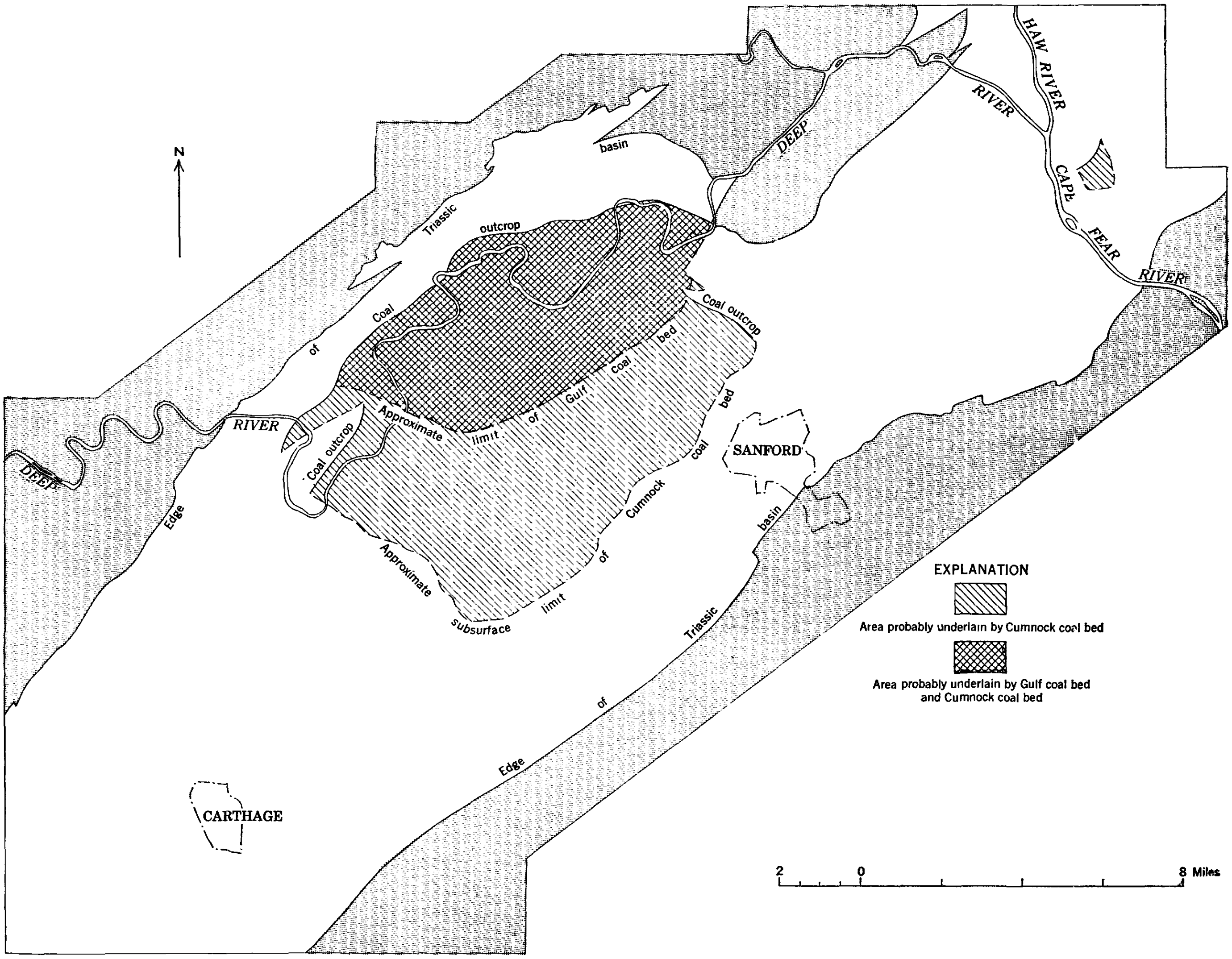


FIGURE 38.—Extent of the Cumnock and Gulf coal beds.

Section of Gulf coal bed in main slope of Carolina mine, 2,500 feet from portal

[About 300 feet down slope from section *E*, shown on pl. 6]

	Feet	Inches
Shale, black, carbonaceous, ferruginous (Blackband)		7
Siltstone, medium dark-gray (N4) or olive-gray (5Y4/1) grains in grayish-black (N2) matrix, carbonaceous		2
Coal, non-banded, bright, abundantly cleated		11
Coal, bony		9
Shale, fissile, medium dark-gray (N4) or dark-gray (N3), carbonaceous ferruginous (Blackband)		3
Siltstone, medium dark-gray (N4) or olive-gray (5Y4/1) grains in grayish-black (N2) matrix, carbonaceous		3

The Cumnock and Gulf coal beds have been measured in 28 drill holes, in eight mines, and in a number of pits and exposures along the coal outcrop. The average thicknesses of these beds in mines and pits are shown in table 9. Closely-spaced measurements, revealing variations in coal thicknesses in the Carolina and Cumnock mines, are shown in plates 5 and 6. Sections of coal and adjacent beds, measured in mines and drill holes north of the Deep River fault, are shown in plate 8; each of the top two rows in plate 8 consists of sections measured at localities along an irregular northeast-trending line approximately parallel to the strike of the beds, and the bottom row consists of sections from holes drilled along a south-trending line approximately perpendicular to the strike of the beds. The sections within each row are in the same relative positions as the localities at which they were measured. All of the holes shown on plate 1 are represented in plate 8 except as follows: hole BDH 10, which has practically the same section as hole BDH 11; holes BDH 1, 5, 7, which were in fault zones and therefore did not obtain satisfactory sections; hole BMDH 1, which was drilled beyond the limit of the coal; hole DH A–5, which did not reach the coal; and the two holes marked SDH on plate 1, for which no records could be found.

TABLE 9.—*Measured thicknesses of coal beds in mines and pits in the Deep River coal field*

[Thicknesses given in inches; numbers in parentheses show shale partings; question marks designate "thicknesses not known"]

Southwest — Northeast

		Gardner Mine [1]		Jones coal pit [2]	Murchison Mine	Black Diamond Mine [1]	Deep River Mine [3]	Gulf Mine	Pits near Gulf [4]	Taylor coal pit [5]	Cumnock Mine [6]	Carolina Mine [7]		McIvor Mine [8]	Near U. S. Hwy. 1 [9]		North of Brickhaven	Goodwin coal pit
Cumnock coal bed	Top bench.	?	Deep River Fault	0	23.5	4 (3) 4	?	2	0	0	0	0	Deep River Fault	0	0	Colon cross structure	0	0
	Main bench	11		8-10	36	18	26	40	72	36	48	37		14-40	10		5	11
	Lower benches.	13 (2) 17		0	2	13 (4) 19	?	2 ?	36	?	13 (6) 7	12		?	0		0	0
Gulf coal bed.		0		0	0	17	?	6	?	24-30 (4-6) 5-6	12	20		0	0		0	0

[1] Measurement of Cumnock bed by John M. McIvor (personal communication).
[2] Measurement by Chance (1885, p. 50).
[3] Measurement by R. B. Jordan (personal communication).
[4] Measurement by A. B. Williams. (See Chance, 1885, p. 41). Abnormal thickness resulting from local deformation.
[5] Measurement by Chance, (1885, p. 39-40).
[6] Measurement by Wilkes (1858, p. 6). This measurement from main shaft. See pl. 5 for measurements in the main slope of this mine.
[7] Section measured in main slope and described in text. See pl. 6 for other measurements in the main slope of this mine.
[8] Reported by A. J. Wakefield (personal communication).
[9] Reported by Emmons (1856, p. 244).

To facilitate the study of lateral lithologic variations, the thickness data for the Cumnock coal bed north of the Deep River fault have been plotted and contoured on plate 7. The thickness of the main bench of the Cumnock bed is shown by patterns. The thickness contours that form the pattern boundaries are shown as solid lines where they are believed to be accurate within 3 inches; elsewhere they are shown as broken lines. Thicknesses of the top bench and lower benches are shown by diagrams on plate 7. The contours on these diagrams show the total thickness of all coal in the top bench and lower benches that lies within 10 feet respectively above, or below, the main bench of the Cumnock coal bed. Thus, by referring to plate 7, it is possible to determine the approximate thickness of the main bench of the Cumnock Coal bed in any part of the coal field north of the Deep River fault and to determine the probable thickness of coal within 10 feet above, or below, that bench. Thickness data on the Gulf coal bed are insufficient to justify contouring, but an indication of the thickness variations of this bed can be obtained by studying the measured sections of plate 8.

CUMNOCK COAL BED

Thickness measurements listed in table 9 indicate that the main bench of the Cumnock coal bed is the most persistent and the thickest bench in the Deep River field. This bench probably underlies the entire area between the coal outcrop and the Deep River fault, although its continuity is interrupted by faults and intrusives. The coal thickness patterns on plate 7, and the measured sections on plate 8, show that this bench is thicker than 42 inches in an elliptical area southeast of Gulf and in an irregular area near Cumnock. Its maximum thickness, except for pockets of coal locally thickened by deformation, is 48 inches in a small area that includes part of the Cumnock mine.

South and east of Cumnock, the main bench becomes rapidly thinner. The eastward thinning within the Carolina mine is indicated by the measured sections on plate 6, which show a decrease in thickness of this bench from 40 inches in the lower workings to 26 inches near the outcrop. Other measurements along the outcrop near this mine range from 24 to 36 inches. The main bench thins rapidly as it nears the Deep River fault south of the Carolina mine, as shown on plate 7.

Southwest of Gulf this bench also becomes thinner, partly because of an original progressive southwestward decrease in the thickness and partly as a result of metamorphism of the coal by diabase intrusions. This metamorphism consists of an alteration of the coal to semianthracite, anthracite, or coke, depending on the nearness of the intrusive mass, and it is accompanied by a thinning of the coal. Because of this metamorphism, the thickness of the main bench is probably more irregular in the southwestern part of the coal-bearing area than is suggested by the generalized patterns on plate 7. Coal near intrusives may be thinner than shown on this map, and pockets of coal far from intrusives may be thicker than indicated. Anthracite was reported in holes BDH 6 and 8 in this part of the field. Semianthracite was encountered in the Deep River mine, where the main bench was only 26 inches thick, and anthracite was encountered in the Black Diamond mine, where the main bench was only 18 inches thick. The coal in the Murchison mine, which was not metamorphosed, was 30 inches thick (this coal was shaly). Some coal near Carbonton has been destroyed by sill-like intrusives, as shown in figure 24.

Coke was encountered in drill holes BMDH D-1 and D-2, west of Cumnock. These holes were drilled in a belt of cross faults and dikes. It is probable that most of the coal in this belt has been metamorphosed and thinned as shown on plate 7. Many of the peculiar indentations in the coal thickness contours in this belt (and elsewhere on pl. 7), emphasize the thinning resulting from metamorphism near intrusives.

The top bench of the Cumnock coal bed is consistently present only south and southwest of Gulf. It appears as a 1-inch layer of coal 16 inches above the main bench in drill hole BDH 3, and as a 2-inch layer 34 inches above the main bench at the Gulf mine. It becomes consistently thicker toward the south and reaches a maximum observed thickness of 30 inches in drill hole BDH 8, where it is only 4½ inches above the main bench (see pl. 8). At the Murchison mine, this bench is 23½ inches thick, but like the main bench which is 44 inches below it, it is shaly. Between BDH 8 and the Murchison mine there is no information as to the thickness of this bench, but it probably has been considerably metamorphosed by the intrusives near Carbonton and Haw Branch. East of Gulf, the top bench has been encountered in only a few of the drill holes. In this part of the field the top bench apparently is represented by discontinuous patches of coal (generally less than 12 inches thick) that are 24 inches to more than 8 feet above the main bench.

As many as three lower benches of coal are present beneath the main bench of the Cumnock coal bed in every mine and drill hole north of the Deep River fault, except in the holes that are located in fault zones. Generally, there are two lower benches, with a combined thickness of 18 to 36 inches, that are separated from each other by a shale parting, less than 12 inches thick, and separated from the main bench by a bed of ferruginous shale, or blackband, usually from 18 to 24 inches thick. Actually, the thicknesses and disposition of these benches vary widely (as shown by the measured sections on pl. 8). The observed total thickness ranges from 38½ inches (in drill hole BDH 9) to 2 inches (at the Gulf mine and in parts of the Carolina mine).

GULF COAL BED

Information on the thickness of the Gulf coal bed is not so detailed as that of the Cumnock bed because only 12 of the 30 holes drilled in the Deep River field went deep enough to test it. Measured sections of this bed, plotted on plate 8, indicate that it is only in a narrow area bordering the coal outcrop between Gulf and Cumnock that the main coal bench in the Gulf bed is thicker than 24 inches. A thin bench below the main bench is present in this area. South, east, and west of this area the lower bench disappears and the main bench becomes thinner, thus following the same pattern of change that exists in the main bench of the Cumnock coal bed. The available data suggest that the Gulf coal bed probably is present throughout the part of the field east of the Black Diamond mine and north of the Deep River fault. There is no direct evidence concerning its extent southwest of the Black Diamond mine, but it probably thins rapidly and does not extend far in that direction.

COAL SOUTH OF THE DEEP RIVER FAULT

CUMNOCK COAL BED

South of the Deep River fault the main bench of the Cumnock coal bed has been observed and measured at only three places: At the Gardner mine, where it is 11 inches thick (anthracite); at the McIvor mine, where it is 14 to 40 inches thick (bituminous); and near U. S. Highway 1, north of Sanford, where it is 10 inches thick (see table 9). Because of nearby dikes and faults, the measurements at the Gardner and McIvor mines do not necessarily indicate the average thicknesses of coal in these parts of the field, nor are they necessarily an indication of the thickness of the coal in the center of the Sanford basin between these two mines, where the coal might be somewhat thicker. Nevertheless, it is unlikely that thicknesses of more than 24 inches exist south of the Deep River fault for the following reasons:

1. There is a progressive thinning of the main bench toward the southeast, south, and southwest, which is revealed by the measurements in drill holes and mine workings already described.

2. Thinning is indicated by the fact that no coal has been observed along the outcrops of the Cumnock formation east of U. S. Highway 1, or southwest of the Gardner mine.

3. There is a progressive decrease, toward the southeast and southwest, in the proportion of the gray and black shale that is associated with coal in the Cumnock formation, and there is a corresponding increase in the proportion of the coarser-grained sediments. This suggests that the environment was less suitable for deposition of coal and shale in the southeastern and southwestern parts of the Sanford basin than it was farther north. It is possible, however, that this southward thinning of the coal and shale may not be so abrupt and consistent

in the deeper part of the Sanford basin as it is along the outcrops, and local areas of coal, as much as 24 to 36 inches thick, may be present in the center of the basin, west of Sanford.

The top bench of the Cumnock coal bed has not been observed south of the Deep River fault, and the lower benches have been measured only at the Gardner mine, where they are shaly and have a combined thickness of 30 inches. These benches may be present over a considerable area south of the Deep River fault, but they are probably too thin, or too shaly, to be of commercial importance.

GULF COAL BED

The Gulf coal bed has not been observed south of the Deep River fault, but it may underlie a small area in the center of the basin, west of Sanford. As noted previously, the main bench of this bed is consistently much thinner than the main bench of the Cumnock coal bed, and it appears to change in thickness in the same manner. For these reasons, it is believed that this bench does not extend far south of the fault, and it is probable that it is not more than a few inches thick in this part of the field.

COAL IN THE DURHAM BASIN

Coal has been discovered at two localities in the southern part of the Durham basin. One locality is about a mile north of Brickhaven, on the south side of the newly paved road from Brickhaven to Moncure (see pl. 1). Coal is exposed in a cut made during road construction and has been mined in an old slope about 300 feet southwest of the road. The slope was inaccessible, but the following section of the coal bed was measured in the road cut.

Section of coal bed 1 mile north of Brickhaven

[In inches]

Clay, medium light-gray (N6), plastic	3
Coal, weathered, with one-sixteenth to one-eighth inch shale partings	5
Shale, carbonaceous, grayish-black (N2)	5
Clay, medium light-gray (N6), with discontinuous bands of grayish-black coaly shale	2
Shale, light olive-gray (5Y6/1), imperfectly bedded, abundant plant fossils	12+

The other coal exposure is 6 miles north of Merry Oaks and 11 miles east of Pittsboro, on a farm owned by Mr. John Goodwin of Apex, N. C. Coal was cut at a depth of 30 feet below the surface in a well drilled behind the farmhouse, and has subsequently been exposed in two pits about 400 feet north of the house. The coal in one of the pits strikes N. 45° E. and dips 15° SE.; the beds exposed in this pit are as follows:

Section of beds measured in Goodwin coal pit

	Feet	Inches
Surface.		
Sandstone, coarse-grained, light-brown (5YR6/4) to pale-brown (5YR5/2) in 3- to 4-inch beds	3	0
Sandstone, coarse-grained, light-brown (5YR6/4) to pale-brown (5YR5/2) matrix, with scattered pebbles of light-gray or yellowish-gray pebbles of quartz or feldspar as much as ½-inch in diameter	2	0
Sandstone, coarse-grained, moderate-brown (5YR4/4) to grayish-red (10R4/2) matrix containing irregular lenses of medium light-gray plastic clay. Abundant light-gray, quartz pebbles, yellowish-gray feldspar pebbles or dark greenish-gray schist pebbles as much as 1 inch in diameter	3	0
Clay, brownish-gray (5YR4/1), plastic		4
Conglomerate, coarse-grained, light brownish-gray (5YR6/1) to pale red (10R6/2) matrix, with light-gray quartz pebbles and light olive-gray or dark greensih-gray schist pebbles as much as 1½ inches in diameter	2	6
Clay, mottled gray and brown, plastic	1	0
Clay, light-gray (N7), alternating with coal ½ inch beds		3
Shale, black, fissile		1
Coal, weathered, with numerous shale partings		11
Shale, black, coaly		4
Clay, light-gray (N7), plastic	1	0
Clay, light-gray (N7), brittle, containing layers of yellowish-gray clay averaging ½ inch in thickness	1	6
Bottom of pit.		

The two exposures of coal in the Durham basin are of interest because they indicate that conditions were locally and temporarily favorable for the formation of coal in this part of the Deep River basin. These coals are tentatively correlated with the Cumnock coal bed in the Sanford basin because they occupy about the same stratigraphic position, and because it seems likely that the time of maximum extent of swamps wherein plant material could accumulate would be the same in the Durham and Sanford basins. At the present time, there is no proof that these two coals are time-equivalents, either of the Cumnock coal bed, or of each other.

The coals of the Durham basin are probably of limited extent and are too thin to be commercially important. This is indicated by the lack of a persistent belt of gray and black shale (similar to that which accompanies the coal in the Sanford basin), by the coarseness of the sediments near the coal (particularly in the Goodwin pit), by the thinness and high shale content of the coal in the two exposures, and by the fact that no other outcrops of coal have been reported in this basin.

ORIGIN AND SIGNIFICANCE OF VARIATIONS IN THE COAL

PROCESSES OF FORMATION OF THE COAL

Variations in extent and thickness of the coal beds are related to episodes in the geologic history of the coal field. To interpret the known variations in the part of the field that has been extensively explored and to visualize the probable extent and thickness of the coal beds in other parts of the field (where fewer data are available) requires an awareness of the processes responsible for the formation and modification of these coals.

The coals of the Deep River coal field were formed from plant material that grew and accumulated in Triassic swamps, was converted to peat, buried, and then changed to coal concurrently with the lithification of the overlying and underlying sediments. Originally, the extent of each coal bed was directly related to the extent of the swamp in which the peat accumulated, and the thickness of each bed was related to the depth and duration of the swamp, to the rate of plant growth and peat accumulation, and to the amount of compaction of the peat that occurred during the coalification process.

The main bench of the Cumnock coal bed originated in the most extensive of the peat-forming swamps in the Deep River basin—this peat bog probably was deepest and most persistent near Cumnock (where the coal is now thickest), or north of Cumnock. The extent of this swamp to the north of the present coal outcrop is not known, but its southern limit is approximately defined by the limit of the Cumnock coal bed, shown in figure 38. Its southern limit is indicated, not only by the known lateral extent and variations in the coal, but also by the textural changes in the other previously described Triassic deposits, which indicate that an area of high ground existed south of the Jonesboro fault during much of the time of Newark deposition. Toward its southern edge, evidence suggests that this swamp was shallower and muddier, and that it produced a peat deposit and ultimately a coal bed that is both thinner and more shaly here than farther north. It is this interpretation of the physiographic conditions during the time of peat accumulation that makes the existence of thick, high-quality coal in the southern and southwestern parts of the Sanford basin seem improbable.

Similarly, textural variations in the sediments indicate that the Colon cross structure was an area of coarse sedimentation during most of the Newark epoch, that no swamps extended across it, and that the main bench of the Cumnock coal bed may never have been connected with the coals of the Durham basin (which may have formed at about the same time).

If it is assumed that plant growth in the Triassic swamps was at least as rapid as present growth in the Dismal Swamp of North Carolina, a rough estimate can be made of the time required to produce the main bench of the Cumnock coal bed. White (White and Thiessen, 1913, p. 87) has suggested that a period of about 100 years is required in the bogs of the North Temperate Zone to produce 1 foot of dense old peat at a depth of 18 feet, after it has been compressed by burial and bacterial action. Ashley (1907, p. 45) estimated that 3 feet of peat were required to produce 1 foot of bituminous coal. Therefore, the plant growth of about 300 years is contained in 1 foot of typical bituminous coal. At this rate, the thickest part of the main bench of the Cumnock coal bed contains the accumulated plant growth of a little more than 1,000 years. Although these rates may not be entirely valid because of the assumptions necessary to determine and apply them to the Triassic coals, they suggest an approximation of the time required to accumulate the plant material contained in the coal. The ultimate compaction and alteration of the peat to coal required an additional period of many millions of years.

Minor irregularities in the thickness of the main bench of the Cumnock coal bed, such as the abrupt variations from 43 to 48 inches in the lower part of the Cumnock mine (shown on pl. 5) and the abnormally thin coal in drill hole BMDH E–1 (shown on pl. 8) are probably the result of local variations in the rate of peat accumulation, or of irregularities on the bottom of the swamp.

The Gulf coal bed was formed from a peat bog that was smaller and shorter-lived than the one in which the main bench of the Cumnock bed originated, and it was deepest in about the same place. The lower benches of the Cumnock coal bed record rather extensive swamps, which were more irregular in outline and less free of inorganic sediment than the swamp that produced the main bench. The top bench of the Cumnock coal bed indicates a swamp that was confined mainly to the area southwest of Gulf and was deepest east of Carbonton. One reason for this westerly confinement of this latest Triassic peat-forming swamp may be that the swamp basin east of Gulf was partly filled by a deposit of sand at this time. The extent of this sand fill, which was thickest near drill hole BMDH E–1, is shown in plate 7. This sand deposit is of importance because it may provide a roof over the main bench of the Cumnock coal bed that would be easier to support during mining than the shale that overlies the Cumnock bed elsewhere in the coal field.

SECONDARY MODIFICATIONS IN THE COAL

The original form and distribution of the Deep River coals and their bituminous rank have subsequently been modified by faulting, by intrusions of diabase, and by erosion.

EFFECTS OF FAULTING

The most obvious effects of faulting are the offsets in the coal beds, which have been described in the chapter on the structure of the Deep River coal field. However, faulting has also caused structural irregularities within the beds, such as drag folds, rolls, and pockets of unusually thin, or unusually thick, coal, caused by squeezing or internal shearing of the beds. These minor structures may affect the coal for tens, or hundreds, of feet away from the larger faults, and in addition to small offsets in the beds they may make mining difficult and unprofitable.

All of the mines have encountered structurally-caused irregularities in the coal. The mines between Carbonton and Cumnock show that most of the coal along the outcrop is affected by deformities produced by movement on the nearby Gulf fault. Thickening and thinning of the coal near the Gulf fault zone in the upper part of the Cumnock mine is described by Chance (1885, p. 35–36), as follows:

> * * * It seems that the upper bench of coal only reached four feet at its thickest points and that it averaged not more than three feet; that in the rooms driven up the dip, rolls were encountered which pinched the coal down to small size, the coal coming in again of normal size in a few feet; * * *.

These effects may be observed near most of the faults in the Carolina mine, but they are particularly evident along the fault zone that goes through the air slope and the main slope just below the coal outcrop. In the McIvor mine, the pinching and swelling of the coal (ranging from 14 to 40 inches) probably is related to the nearby faults and intrusives; therefore it is probable that the change in thickness is of structural rather than depositional origin.

EFFECTS OF INTRUSIONS

Diabase intrusives in the Deep River coal field are in the form of dikes (most of which are nearly vertical and cut across the coal beds at high angles), and in the form of sills or sill-like masses (which extend laterally from the dikes roughly parallel to, and at varying distances from, the coal beds). These two forms of intrusives usually have metamorphic effects on deeply buried coal, as follows:

Dikes: Alter the coal to cinder coal or natural coke in a zone several feet wide on both sides of the intrusive.

Sills or sill-like masses: If in the coal bed, they replace or destroy the coal. If along the top or bottom of the coal bed, they alter the coal to natural coke in a zone from several inches to several feet wide, bordering the intrusive contact. If a short distance above or below the coal bed, they alter the coal to anthracite or semianthracite. If at a greater distance above or below the coal bed, they may have no effect on the coal.

In the Deep River field, coke, semianthracite, and anthracite have been formed by metamorphism of bituminous coals. Metamorphism is accompanied by reduction in the thickness of the beds and, in many places, by brecciation or deformation of the beds (which increases the difficulties of mining). For this reason, and also because the markets for coke and anthracite are not the same as for bituminous coal, it is important to know the extent of coke and anthracite in the field, the distribution of intrusives that may have altered the coal, and the conditions necessary to produce such alteration.

Natural coke, or "carbonite" has been observed at several localities in the Sanford basin. Chance (1885, p. 30) found coke in one of the pits he opened along the coal outcrop at Farmville, only 10 feet from a place where bituminous coal had been mined. He also noted the occurrence of coke along one of the dikes in the Cumnock mine. Campbell and Kimball do not refer to the coke in their report, but Roberts (1928, p. 113) calls attention to the existence of coke in the Cumnock mine as follows:

> * * * Similar natural coke also occurs in a number of the pits of the Deep River Triassic area in North Carolina and at present is found in the pits now opened up near Egypt. Specimens from the Carolina pits show diabase and coke adhering to each other and often masses of coke will be included in the diabase and the converse is equally true.

Coke was encountered in three drill holes west of Cumnock. In drill hole BDH 10, the main bench of the Cumnock coal bed was altered to a bed of coke 48½ inches thick (which was 29½ inches below a diabase intrusive). In drill hole BMDH D–1, the main bench of the Cumnock coal bed was altered to a bed of coke 29 inches thick. Several thin diabase masses were encountered within a distance of 12 feet above the main bench, and one mass was in contact with the top of this bench (see pl. 8). The uppermost of the lower benches was also coked, but a 4-inch bed (10 inches below it) was little affected. In drill hole BMDH D–2, the top bench of the Cumnock coal bed was altered to a bed of coke about 12 inches thick;[11] the nearest intrusive in this hole was 76 feet above the coal. The main bench and lower benches were not affected.

Because none of the beds of coke in the Deep River coal field are now open to view, the lateral extent of coking and the progressive physical and chemical changes in the coal with regard to distance from an intrusive cannot be determined precisely. It is unfortunate that such information was not obtained from the Cumnock mine before it was flooded. The distribution of mine workings around the two dikes in the Cumnock mine (see pl. 5) suggests that the metamor-

[11] Originally hole BMDH D–2 penetrated 16 inches of coke. Later the hole became blocked, and it was then deflected above the coke bed. The deflected hole cut 10¾ inches of coke. The combined drill log shows 12 inches.

phism does not extend far from the intrusive and suggests further that it ends abruptly. The log of hole BMDH D–1 shows that coke is formed when the diabase is in contact with the coal, but none of the holes gives positive information as to the distance coke may be formed away from an intrusive. In holes BDH 10 and BMDH D–2, the vertical distances of the coke from the nearest diabase has no necessary relationship to the lateral extent of coking, because the coke in each hole probably was formed by dikes or sills that intruded the coal beds a short distance horizontally from the hole.

Studies of coke in other fields provide information that may be used to estimate the extent of coking in the Deep River field. Roberts (1928, p. 114) reported that coke extends as much as 4⅔ feet from intrusives in the Richmond Triassic coal field of Virginia. Raistrick and Marshall (1939, p. 245) described the metamorphic effects produced by the intrusion of a basalt dike, 17 feet thick, into a coal bed in the Northumberland coal field of Great Britain, as follows:

> The stages in the alteration of the coal are best appreciated by observing the successive changes in the coal as the dike is approached from a position outside its zone of influence.
>
> The first apparent change in the seam is the development of innumerable fine, cleat-like fractures, which make the coal much more tender and friable than it is normally. Then within a short distance the coal changes quite abruptly into a massive, compact coke which retains no suggestion of the original lamination or jointing. The brilliant lustre of the normal coal is also completely destroyed. This change from the normal coal to the cinder is very abrupt, and indeed almost presents the appearance of a definite break at a distance of between 4 and 5 feet from the dike. Towards the dike the coal becomes harder and tougher, until, at the actual contact with the igneous mass, it is almost rock-like.

In the Anthracite-Crested Butte coal field in Colorado, Dapples (1939, p. 386) found that an intrusive 200 feet thick had coked the coal for a maximum distance of 4 feet, at calculated temperatures ranging from about 700° C. at the intrusive contact to about 460°–500° C. at a distance of 4 feet from the intrusive (the temperature of the intrusive was estimated at 900° C.). The temperatures of the diabase and basalt dikes in the Richmond and Northumberland fields, like those in the Deep River field, may have been about 1,000° C. or a little higher, but this greater temperature produced a coked zone no more than a fraction of a foot wider than in the Anthracite-Crested Butte field. Coke might be formed at greater distances in the event that a dike had been kept open for a long time as a channel for the upward movement of magma, as noted by Stutzer and Noe (Stutzer, 1940, p. 229), but there is no evidence that this has occurred in the Deep River field.

Evidence from other fields shows that coke is not usually formed at distances greater than 4 or 5 feet from an intrusive, despite large differences in sizes of intrusives and moderate differences in temperature. We may expect, therefore, that the occurrence of coke in the Deep River field is limited, in general, to a zone 4 to 5 feet wide bordering each diabase intrusive, and that more extensive coked areas exist only where sills lie along the top or bottom of a coal bed—a situation thus far observed in only one drill hole and at only one locality along the outcrop. The greatest proportion of coke is to be expected where intrusives are most abundant and extensive, but inasmuch as coke is present only near intrusives (where mining conditions are poor), probably very little coke can be mined at a profit.

Anthracite is present extensively in the southwestern part of the coal-bearing area. It has been mined at the Black Diamond and Gardner mines, and Emmons (1856, p. 252–253) described it also on the old Wilcox plantation south of Carbonton. The coal at the Deep River mine is reported to be semianthracite. In drill hole BDH 6, all the benches of the Cumnock coal bed are anthracite, but the Gulf bed is bituminous. The same benches are metamorphosed in drill hole BDH 8, but apparently they have been partly coked by a nearby dike—probably the one that passes near this hole on the surface (see pl. 1).

Certain conditions of heat and pressure are required to produce anthracite and semianthracite. In the Deep River field the heat is supplied by intrusives and the pressure is supplied by the weight of the overlying rock. To heat a coal bed enough to form anthracite over a considerable area requires a laccolith, sill, or sill-like intrusive that extends for some distance along the bedding. Less heat is needed to form anthracite than to form coke, however, and still less heat is needed to produce semianthracite. To alter the coal to anthracite, therefore, the intrusive should not be along, or in contact with, the coal bed (where it will produce coke), nor should it be so far above, or below, the bed that the heat imparted to the coal is insufficient for anthracitization.

The conditions necessary for the development of anthracite have been studied in other coal fields where the metamorphism is related to intrusives. In regard to the Anthracite-Crested Butte field, Dapples (1939, p. 398) noted:

> * * * both temperatures of 300°–350° C. and pressures of the order of magnitude of 1,400–2,800 atmospheres are essential for anthracitization, for even in areas near intrusive bodies, neither agency is capable of producing anthracite without the other.

The formation of anthracite by heat from intrusive sills, or sheets, in the Yampa coal field, Colorado, was studied by Eby (1925, p. 250) who found the following relationships between metamorphism and distance:

In a vertical direction, a sheet 75 ft. thick has affected coals up to an average of 80 ft. above the sheet. Analyses show that true anthracite is formed at least as far as 45 ft. above the sheet in this field and true semianthracite as far as 55 ft. above the sheet, provided the coals are not affected by dikes. It is also shown that a 200-ft. sheet or sill will alter to a true anthracite a low-rank coal occurring 26 ft. below the sheet; and to a semianthracite a coal occurring 44 ft. below the sheet.

In the Deep River field, mining and drilling have not been extensive enough to completely outline any areas of anthracite or semianthracite, nor to establish with certainty their relationships to the intrusives responsible for the metamorphism of the coal. The most diagnostic evidence appears in the record of drill hole BDH 6. In this hole, all the benches of the Cumnock coal bed were anthracite; apparently, this was produced by heat from a sill, 144 feet 8 inches thick, which lies 15 feet 10 inches above the top bench. The lowest coal altered to anthracite was 48 feet below the sill; the highest unmetamorphosed bed was the Gulf coal bed, 53 feet below the sill. In this case, the limit of anthracitization was about 50 feet below the intrusive. This agrees closely with the conditions observed by Eby. The temperatures of the coals during this metamorphism may have been within, or above, the 300° to 350° C. range suggested by Dapples, inasmuch as the intrusive itself probably was 1,000° C. or more at the center, but the pressure on the coal was probably less than the pressure he calculated for the Anthracite-Crested Butte field. His estimates of pressure were based on a probable overburden of 6,700 to 17,000 feet of sediments and an intrusive 3,000 feet thick. In the Deep River field, the overburden probably consisted of no more than 6,000 to 7,000 feet of sediments and of an intrusive less than 200 feet thick.

Sill-like intrusives in the Cumnock formation from Haw Branch to Gulf are stratigraphically lowest in the vicinity of Carbonton, and they are progressively higher in the formation southwest toward Haw Branch and northeast toward Gulf. The relationships of these intrusives to the coal beds are shown in figure 24. In the vicinity of Carbonton, the intrusives are in, or very near, the coal beds, and the coal probably has been metamorphosed to coke or anthracite, or it has been destroyed. At the Black Diamond mine, where the lowest sill is 115 feet above the coal, the benches in the Cumnock coal bed are anthracite. At the Deep River mine, where the lowest intrusive is 170 feet above the coal, the benches in the Cumnock bed are reported to be semianthracite, and at the Gulf mine, where the lowest sill is 260 feet above the coal, the benches are bituminous. The bituminous coal in the Murchison mine is about 500 feet below the thickest sill, although there are some thin sills and dikes nearer the coal (see pl. 1).

It should not be inferred that the sills shown in figure 24 were entirely responsible for the alteration of the coal at the Black Diamond and Deep River mines. The evidence from drill hole BDH 6 and the Yampa coal field shows that metamorphism does not usually occur in coals at distances of 100 feet or more from the intrusive. Much of the additional heat required to alter the coal at these mines probably was supplied by dikes along the nearby Gulf fault and by sills nearer the coal but not exposed along the outcrop. These conditions suggest, therefore, that where there are many intrusives of varying sizes, shapes, and distances from the coal (as in the area south of the Deep River mine), the general temperature of the rocks may have been raised sufficiently high at the time of intrusion to produce more anthracite here than where only one intrusive mass was present.

The alteration of coal to anthracite or semianthracite is accompanied by a reduction in the thickness of the coal bed. This was recognized by Campbell and Kimball (1923, p. 73), who estimated that the average amount of reduction in changing from bituminous to anthracite is about 35 percent. Their estimates were based on examples of the thinning of beds as a result of metamorphism in the Cerrillos coal field, New Mexico, and in Routt County, Colorado. Dapples (1939, p. 381) noted a decrease of 10 to 30 percent in the thickness of metamorphosed coal beds in the Anthracite-Crested Butte coal field. Campbell and Kimball calculated that the coal at the Black Diamond mine would have ranged in thickness from 2 feet 5¾ inches to 4 feet 4¾ inches before it was metamorphosed. If a correction of 25 percent is applied to the measured thicknesses of coals in the Black Diamond and Gardner mines, and in drill holes BDH 6 and 8, the results are as follows:

Estimated changes by metamorphism in thickness of coal benches in the Cumnock coal bed

Actual thickness (altered coal)	Black Diamond mine		BDH 6		BDH 8		Gardner mine	
	Feet	Inches	Feet	Inches	Feet	Inches	Feet	Inches
Top bench	------	8	1	4	2	6	------	------
Main bench	1	6	2	10	3	1	------	11
Lower bench	1	1	1	1	------	6	1	1
Do	1	7	------	------	1	0	1	5
Corrected thickness (unaltered coal)								
Top bench	------	11	1	9	3	4	------	------
Main bench	2	0	3	9	4	1	1	3
Lower bench	1	5	1	5	------	8	1	5
Do	2	1	------	------	1	4	1	11

These computations show that relatively thick bituminous coal may be present in some parts of the field south and east of the Black Diamond mine, where the beds are far enough from intrusives to have escaped metamorphism.

The effects of metamorphism of coal beds by diabase intrusives in the Deep River coal field may be summarized as follows:

1. Coke has been formed in zones usually no more than 4 or 5 feet wide bordering intrusives that cut the coal or are in contact with it.

2. Anthracite has been formed where sills or sill-like intrusives are within 50 feet of the coal, or possibly at greater distances where there are many intrusives in the vicinity to help supply the heat. Anthracitization is accompanied by a reduction in thickness of the coals that may average as much as 25 percent.

3. Anthracite and coke are probably most extensive in the general vicinity of Carbonton where the sill-like intrusives are largest and nearest the coal. The extent of coal metamorphism in this area cannot be accurately predicted until more information on the shape and extent of intrusives has been determined by diamond drilling.

4. Because the coke is limited to zones near intrusives, where mining conditions are poor, very little of it can be mined profitably. Because anthracite is usually more remote from the intrusives, some of it can probably be mined at a profit if mining procedures are efficiently adjusted to the structure of the beds.

EFFECTS OF EROSION

Erosion has had little effect on the coal now present in the Deep River field, but it has destroyed a large part of the coal originally present. Coal once extended an unknown distance northwest of the present coal outcrop, but it has been eroded since the Triassic. Judging from the fact that the thickest existing coal in the field is near Cumnock, along the coal outcrop, it seems probable that some of the eroded coal was at least as thick as that which remains.

CHARACTERISTICS OF THE COAL

COMPOSITION

Chemical compositions of coals in the Sanford and Durham basins are listed in table 10. Analyses of coals from the top bench are shown at the top of the table, followed by analyses of coals from the main bench and lower benches of the Cumnock coal bed and from the Gulf coal bed. The composition of the coal from the Goodwin pit in the Durham basin is shown at the bottom of the table. To facilitate the comparison of lateral lithologic changes in composition, the individual analyses for each coal bench in the Sanford basin are listed in the order of geographic position of the sample, beginning at the northeastern end of the basin. The analyses are listed in three forms designated A, B, and C. Form A is the composition of the coal as received by the laboratory; form B is the composition computed on a moisture-free basis; and form C is the composition on a moisture- and ash-free basis. All of the analyses in this table are of bituminous coals, except numbers C–24682 (top bench in drill hole BMDH D–2) and C–27088 (main bench in drill hole BMDH D–1); both of these analyses are of coke.

The analyses listed in table 10 were made since 1920 at the Coal Constitution Laboratory of the U. S. Bureau of Mines. A large number of analyses of Deep River coals were made by various chemists prior to 1900. Those giving compositions of coals not analyzed since 1920 are listed in table 11. The first analysis in this table is of coke; the others are of either anthracite or bituminous coal, as indicated in the column on the right side of the table. No chemical analyses have been made of the anthracite coals in this field since before 1900.

The coals of the Deep River field are bituminous, except where metamorphosed by intrusives. There is a considerable range of compositions and heating values among the bituminous coals, however, as indicated by the analyses in table 10. From Gulf to the Carolina mine, the fixed carbon content of the main bench of the Cumnock coal bed ranges from 52.6 to 59.6 percent on an "as received" basis; the ash content ranges from 5.8 to 15.9 percent; the sulfur content ranges from 1.1 to 4.3 percent, and the heating value ranges from 12,190 to 14,030 B. t. u. The only available analysis of unaltered coal from the top bench is from drill hole BMDH DR–2, where this coal has a fixed carbon content of 63.9 percent, an ash content of 6.3 percent, a sulfur content of 1.2 percent, and a heating value of 14,460 B. t. u. (the highest heating value of any coal tested in this field).

The lower benches in this part of the field have fixed carbon contents ranging from 38.3 to 59.0 percent, ash contents ranging from 13.1 to 35.7 percent, sulfur contents ranging from 1.7 to 4.1 percent, and heating values ranging from 9,510 to 13,200 B. t. u. The Gulf coal bed has fixed carbon contents ranging from 34.6 to 58.1 percent, ash contents ranging from 8.4 to 38.0 percent, sulfur contents ranging from 1.7 to 4.9 percent, and heating values ranging from 8,890 to 13,700 B. t. u. These figures show that the main bench of the Cumnock coal bed (the thickest and most persistent bench in the field) has the best coal, with the exception of some areas of coal in the top bench.

TABLE 10.—*Chemical analyses of drill cores and mine samples from the Deep River coal field, North Carolina*

[Forms of analysis: A—Coal as received; B—coal moisture free; C—coal moisture and ash free. Analyses by U. S. Bureau of Mines Coal Constitution Laboratory, H. W. Cooper, Chemist in charge.]

Location of sample	Thickness of coal analyzed (inches)	Laboratory number	Form of analysis	Proximate analysis				Ultimate analysis					Calorific value (B. t. u.)	Air-dry loss	Fusibility of ash			Agglutinating index [1]	Specific gravity
				Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur			Initial deformation temperature (°F)	Softening temperature (°F)	Fluid temperature		
Sanford Basin, Cumnock coal bed, top bench																			
Diamond-drill hole BMDH D-2: Footage 1,507′2″–1,508′3⁄4″	10¾	C-24682 (coke)	A	2.0	13.8	77.3	6.9	4.1	81.8	2.1	3.3	1.8	14,040	1.4	2,200	2,420	2,580		1.439
			B		14.1	78.9	7.0	3.9	83.5	2.1	1.7	1.8	14,330						
			C		15.2	84.8		4.2	89.8	2.3	1.7	2.0	15,420						
Diamond-drill hole BMDH DR-2: Footage 2,328′0″–2,329′0″	12	D-5907	A	1.3	28.5	63.9	6.3	5.1	81.2	2.1	4.1	1.2	14,460	.6	2,080	2,150	2,420	9.0	1.32
			B		28.9	64.7	6.4	5.0	82.2	2.1	3.1	1.2	14,650						
			C		30.9	69.1		5.4	87.8	2.2	3.4	1.2	15,650						
Murchison Mine: Face 2—right	15	A-95548	A	2.3	15.7	59.8	22.2					2.5	11,530	1.5		2,810			
			B		16.1	61.2	22.7					2.6	11,800						
			C		20.8	79.2						3.3	15,280						
Sanford Basin, Cumnock coal bed, main bench																			
McIvor mine: Face break-through between slope and right air course	13	A-95552	A	2.7	26.3	54.3	16.7					5.3	12,350	2.2		2,230			
			B		27.0	55.8	17.2					5.4	12,700						
			C		32.6	67.4						6.5	15,330						
McIvor mine: Face break-through between slope and left air course.	12	A-95553	A	2.8	27.0	54.2	16.0					4.9	12,350	1.9		2,210			
			B		27.8	55.8	16.4					5.0	12,710						
			C		33.3	66.7						6.0	15,210						
McIvor mine: Left break-through 80 feet from portal	13	A-95554	A	3.2	26.4	53.1	17.3					4.6	12,170	2.3		2,240			
			B		27.3	54.8	17.9					4.8	12,570						
			C		33.3	66.7						5.8	15,310						
McIvor mine: Composite of samples A-95552, A-95553, A-95554.		A-95555	A	2.9	26.4	54.0	16.7	4.7	66.9	1.6	5.2	4.9	12,290	2.1					
			B		27.2	55.6	12.2	4.5	69.0	1.7	2.6	5.0	12,660						
			C		32.9	67.1		5.4	83.3	2.0	3.2	6.1	15,290						
Carolina mine: Face of No. 1 left entry, 75 feet from foot of main slope.	39	83960	A	1.8	32.5	58.8	6.9	5.2	77.1	2.1	6.3	2.4	13,890						
			B		33.1	59.9	7.0	5.1	78.5	2.1	4.9	2.4	14,140						
			C		35.6	64.4		5.5	84.4	2.3	5.2	2.6	15,200						
Carolina mine: Rib of left air course, 700 feet from portal.	36	85590	A	2.3	32.4	57.2	8.1					2.2	13,630						
			B		33.2	58.5	8.3					2.3	13,950						
			C		36.2	63.8						2.5	15,210						
Carolina mine: No. 1 cross entry 100 feet in, by slope air course.	36	85591	A	1.7	32.2	58.4	7.7					2.5	13,790						
			B		32.8	59.4	7.8					2.5	14,030						
			C		35.5	64.5						2.8	15,220						
Carolina mine: Main slope, 100 feet out by face and 750 feet from portal.	36	85605	A	1.9	32.1	58.8	7.2					2.2	13,930						
			B		32.7	59.9	7.4					2.2	14,190						
			C		35.3	64.7						2.4	15,330						
Carolina mine: Composite of samples 85590, 85591, 85605.		85592	A	2.0	32.4	58.1	7.5	5.1	76.5	1.9	6.7	2.3	13,810						
			B		33.0	59.3	7.7	5.0	78.0	1.9	5.1	2.3	14,090						
			C		35.8	64.2		5.4	84.5	2.1	5.5	2.5	15,260						
Carolina mine: Right side No. 2 gangway at No. 1 right entry.	34	C-89024	A	3.2	32.0	57.6	7.2	5.3	75.7	2.0	8.2	1.6	13,630	1.8	2,600	2,680	2,750	8.2	
			B		33.1	59.5	7.4	5.1	78.2	2.0	5.7	1.6	14,070						
			C		35.7	64.3		5.5	84.4	2.2	6.2	1.7	15,200						
Carolina mine: North wall airway 100 feet from portal	31	D-22822	A	3.8	33.9	56.5	5.8	5.5	76.0	2.0	8.2	2.5	13,750	2.0	1,990	2,210	2,500		
			B		35.2	58.8	6.0	5.2	79.0	2.1	5.1	2.6	14,290						
			C		37.5	62.5		5.6	84.0	2.2	5.5	2.7	15,200						
Carolina mine: 100 feet in by 7 left No. 3 right	35	D-46425	A	2.3	30.4	54.3	13.0	4.9	70.9	1.5	5.7	4.0	12,810		2,100	2,310	2,570		1.41
			B		31.1	55.6	13.3	4.7	72.6	1.5	3.8	4.1	13,110						
			C		35.9	64.1		5.4	83.7	1.7	4.5	4.7	15,120						

TABLE 10.—*Chemical analyses of drill cores and mine samples from the Deep River coal field, North Carolina*—Continued

Location of sample	Thickness of coal analyzed (inches)	Laboratory number	Form of analysis	Proximate analysis: Moisture	Proximate analysis: Volatile matter	Proximate analysis: Fixed carbon	Proximate analysis: Ash	Ultimate analysis: Hydrogen	Ultimate analysis: Carbon	Ultimate analysis: Nitrogen	Ultimate analysis: Oxygen	Sulfur	Calorific value (B. t. u.)	Air-dry loss	Fusibility of ash: Initial deformation temperature (°F)	Fusibility of ash: Softening temperature (°F)	Fusibility of ash: Fluid temperature	Agglutinating index [1]	Specific gravity
Sanford Basin, Cumnock coal bed, main bench																			
Cumnock mine: Room 1 off No. 1 rise	36	85446	A	2.5	31.0	56.6	9.9					2.9	13,240						
			B		31.7	58.1	10.2					3.0	13,570						
			C		35.3	64.7						3.3	15,110						
Cumnock mine: Room 10 on right side of No. 1 slope	39½	85447	A	1.8	32.2	59.6	6.4					1.8	14,030						
			B		32.8	60.6	6.6					1.8	14,280						
			C		35.1	64.9						1.9	15,280						
Cumnock mine: Room 13 off No. 1 slope	43½	85448	A	4.2	31.9	54.9	9.0					1.9	13,250						
			B		33.3	57.3	9.4					2.0	13,830						
			C		36.7	63.3						2.2	15,260						
Cumnock mine: Room 8 off No. 1 slope	43¾	85449	A	1.7	34.1	56.6	7.6					1.8	13,770						
			B		34.7	57.6	7.7					1.9	14,010						
			C		37.6	62.4						2.0	15,170						
Cumnock mine: Composite of samples 85446, 85447, 85448, 85449.		85450	A	2.5	32.0	57.3	8.2	5.3	75.5	2.0	7.0	2.0	13,620						
			B		32.9	58.7	8.4	5.1	77.5	2.0	4.9	2.1	13,970						
			C		35.9	64.1		5.6	84.6	2.2	5.3	2.3	15,260						
Diamond-drill hole BMDH D-1: Footage 874'4"–876'5"	25	C-27088 (coke)	A	6.1	8.3	70.1	15.5	1.8	73.3	1.0	7.3	1.1	10,930	5.5	2,270	2,300	2,420		1.944
			B		8.8	74.7	16.5	1.2	78.1	1.1	2.0	1.1	11,640						
			C		10.6	89.4		1.4	93.5	1.3	2.5	1.3	13,930						
Diamond-drill hole BMDH D-2: Footage 1,510'1"–1,513'0"	35	C-24683	A	1.9	30.6	55.8	11.7	5.1	73.8	1.9	4.7	2.8	13,280	1.2	2,130	2,260	2,480		1.378
			B		31.2	56.9	11.9	5.0	75.2	1.9	3.1	2.9	13,540						
			C		35.4	64.6		5.6	85.4	2.2	3.5	3.3	15,380						
Diamond-drill hole BMDH E-1: Footage 975'4"–977'9"	29	C-28759	A	1.9	30.4	54.8	12.9	5.0	72.6	1.8	5.2	2.5	13,070	1.0	2,180	2,410	2,520	7.7	1.386
			B		31.0	55.9	13.1	4.9	74.0	1.9	3.5	2.6	13,320						
			C		35.7	64.3		5.6	85.1	2.1	4.3	2.9	15,330						
Diamond-drill hole BMDH E-2: Footage 1,887'1"–1,890'½"	35	C-27572	A	4.6	27.2	55.9	12.3	5.1	70.9	1.7	6.6	3.4	12,830	3.8	2,050	2,140	2,350		1.404
			B		28.5	58.6	12.9	4.8	74.3	1.8	2.6	3.6	13,440						
			C		32.7	67.3		5.5	85.2	2.1	3.1	4.1	15,430						
Diamond-drill hole BMDH DR-1: Footage 2,277'2"–2,281'1"	8	C-97931	A	.8	27.2	56.1	15.9	4.7	70.5	1.7	2.9	4.3	12,830		2,000	2,210	2,420	9.5	1.43
			B		27.4	56.5	16.1	4.6	71.1	1.7	2.2	4.3	12,930						
			C		32.6	67.4		5.5	84.7	2.1	2.5	5.2	15,410						
Diamond-drill hole BMDH DR-2: Footage 2,330'5"–2,333'10"	29	D-5908	A	3.7	28.0	52.6	15.7	4.6	69.2	1.5	6.9	2.1	12,190	3.0	2,000	2,080	2,210	8.7	1.45
			B		29.1	54.6	16.3	4.3	71.9	1.6	3.7	2.2	12,660						
			C		34.7	65.3		5.1	85.9	1.9	4.5	2.6	15,120						
Murchison mine: Face 4, room 2 right	29¼	A-95543	A	3.2	16.1	60.8	19.9					3.5	11,830	2.5		2,590			
			B		16.7	62.8	20.5					3.6	12,220						
			C		21.0	79.0						4.6	15,380						
Murchison mine: Left air course, 30 feet above 3 left	27	A-95544	A	3.7	15.9	57.9	22.5					2.9	11,280	3.1		2,620			
			B		16.5	60.1	23.4					3.1	11,710						
			C		21.5	78.5						4.0	15,290						
Murchison mine: Main slope at 3 left	31	A-95545	A	2.6	16.1	62.0	19.3					3.0	12,000	1.8		2,590			
			B		16.6	63.6	19.8					3.1	12,310						
			C		20.7	79.3						3.9	15,350						
Murchison Mine: Composite of samples A-95543, A-95544, A-95545.		A-95546	A	3.1	15.9	60.4	20.6	4.0	66.3	1.5	4.4	3.2	11,740	2.5					
			B		16.4	62.3	21.3	3.8	68.5	1.5	1.6	3.3	12,120						
			C		20.9	79.1		4.8	87.0	1.9	2.2	4.1	15,400						

Sanford Basin, Cumnock coal bed, lower benches																			
Carolina mine: No. 1 left entry off main slope	29	85593	A	2.0	29.0	39.2	29.8					2.7	10,320		2,060	2,150	2,210		
			B		29.6	40.0	30.4					2.8	10,530						
			C		42.5	57.5						4.0	15,130						
Carolina mine: No. 1 left entry off main slope	21	85594	A	1.7	29.0	41.0	28.3					3.2	10,520		2,030	2,150	2,240		
			B		29.5	41.7	28.8					3.3	10,700						
			C		41.5	58.5						4.6	15,040						
Carolina mine: Composite of samples 85593 and 85594		85595	A	1.8	29.0	40.2	29.0	4.4	57.2	1.7	4.8	2.9	10,450						
			B		29.5	40.9	29.6	4.2	58.3	1.7	3.2	3.0	10,650						
			C		41.9	58.1		6.0	82.7	2.4	4.6	4.3	15,120						
Carolina mine: Main slope opposite 7 left	23	D-46427	A	1.4	26.9	37.6	34.1	4.0	53.3	1.4	4.1	3.1	9,650		2,050	2,130	2,360		1.59
			B		27.2	38.2	34.6	3.9	54.0	1.4	3.0	3.1	9,790						
			C		41.7	58.3		5.9	82.6	2.1	4.6	4.8	14,970						
Diamond-drill hole BMDH D-1: Footage 880′3″–880′6″	3	C-27087	A	2.0	22.3	59.0	16.7	4.6	69.8	1.9	3.6	3.4	12,480	1.3	2,070	2,170	2,310		1.448
			B		22.8	60.2	17.0	4.4	71.2	1.9	2.0	3.5	12,730						
			C		27.4	72.6		5.3	85.8	2.3	2.4	4.2	15,350						
Diamond-drill hole BMDH E-1: Footage 979′6″–981′2″	17¼	C-28760	A	1.6	31.7	53.6	13.1	5.0	73.1	1.9	5.2	1.7	13,200	.8	2,300	2,410	2,510	7.5	1.375
			B		32.2	51.5	13.3	4.9	74.3	2.0	3.8	1.7	13,410						
			C		37.2	62.8		5.7	85.7	2.3	4.3	2.0	15,470						
Diamond-drill hole BMDH E-1: Footage 981′8″–983′½″	14	C-28761	A	1.3	28.8	45.8	24.1	4.3	61.6	1.7	4.2	4.1	11,220	.4	2,080	2,270	2,400	9.4	1.511
			B		29.2	46.4	24.4	4.2	62.4	1.7	3.1	4.2	11,370						
			C		38.6	61.4		5.6	82.5	2.2	4.2	5.5	15,030						
Diamond-drill hole BMDH 2: Footage 1,433′4″–1,435′10″	21½	C-47760	A	1.3	28.1	48.7	21.9	4.5	64.7	1.7	4.5	2.7	11,710	.3	2,050	2,180	2,380		1.469
			B		28.5	49.3	22.2	4.4	65.5	1.7	3.5	2.7	11,860						
			C		36.6	63.4		5.7	84.2	2.2	4.4	3.5	15,240						
Diamond-drill hole BMDH E-2: Footage 1,891′11″–1,892′7″	8	C-28506	A	1.3	25.4	38.3	35.0	3.8	53.2	1.4	4.4	2.2	9,510	.5	2,360	2,460	2,650	8.1	1.615
			B		25.8	38.7	35.5	3.7	53.9	1.5	3.2	2.2	9,640						
			C		39.9	60.1		5.8	83.4	2.2	5.2	3.4	14,930						
Murchison mine: Face 4, room 2 right	2	A-95547	A	6.9	13.7	43.7	35.7					3.8	8,460	6.1		2,610			
			B		14.7	47.0	38.3					4.1	9,090						
			C		23.9	76.1						6.6	14,730						
Sanford Basin, Gulf coal bed																			
Carolina mine: Main slope at 5 right, 150 feet west	23	D-46426	A	2.2	32.7	37.1	28.0	4.5	57.1	1.3	5.2	3.9	10,510		1,940	2,000	2,210		1.52
			B		33.4	38.0	28.6	4.4	58.5	1.3	3.2	4.0	10,750						
			C		46.8	53.2		6.1	81.9	1.9	4.5	5.6	15,050						
Diamond-drill hole BMDH D-1: Footage 912′11″–913′11″	12	C-27089	A	1.9	26.7	55.6	15.8	4.8	70.3	1.8	3.9	3.4	12,730	1.3	1,940	2,010	2,250		1.427
			B		27.2	56.7	16.1	4.7	71.7	1.9	2.2	3.4	12,970						
			C		32.5	67.5		5.6	85.4	2.2	2.7	4.1	15,460						
Diamond-drill hole BMDH E-1: Footage 1,011′0″–1,013′¼″	15½	C-28940	A	1.1	38.6	43.7	16.6	4.7	68.8	1.6	5.8	2.5	12,300	.5					1.450
			B		39.0	44.3	16.7	4.6	69.6	1.6	4.9	2.6	12,430						
			C		46.9	53.1		5.6	83.6	2.0	5.7	3.1	14,930						
Diamond-drill hole BMDH 2: Footage 1,460′11″–1,463′0″	25	C-47761	A	2.8	30.7	58.1	8.4	5.3	76.2	2.0	6.4	1.7	13,700	1.9	2,050	2,330	2,600	7.7	1.334
			B		31.5	59.8	8.7	5.1	78.4	2.0	4.1	1.7	14,090						
			C		34.5	65.5		5.6	85.9	2.2	4.4	1.9	15,430						
Diamond-drill hole BMDH DR-1: Footage 2,318′0″–2,318′10½″	7½	C-97932	A	1.3	26.1	34.6	38.0	3.7	48.7	1.1	3.6	4.9	8,890	.7	1,920	2,030	2,310	12.8	1.72
			B		26.4	35.1	38.5	3.6	49.3	1.1	2.5	5.0	9,000						
			C		43.0	57.0		5.9	80.1	1.8	4.1	8.1	14,630						
Durham Basin																			
Goodwin prospect, Chatham County, 11 mi. east of Pittsboro.	11	C-76882	A	16.9	25.7	40.2	17.2					0.6	8,700						
			B		30.9	48.3	20.8					.8	10,470						
			C		39.0	61.0						1.0	13,220						

[1] Ratio of silican carbide to coal 15–1; crushing strength in kilograms.

TABLE 11.—*Analyses published before 1900 of coals not subsequently analyzed*

Coal beds and locations	Analyst	Source	No.	Water at 115° C.	Volatile matter	Fixed carbon	Ash	Sulfur	Rank
Cumnock:									
Main bench:									
Farmville	Battle	Chance [1]	1	0.90	4.75	68.33	25.10	0.92	Coke.
Do	do	do	2	1.79	29.56	58.30	7.46	2.89	Bituminous.
Do	do	do	3	1.95	30.54	58.47	6.85	2.19	Do.
Taylor coal pit	do	do.[2]	4	1.67	35.45	55.39	5.46	2.03	Do.
Gulf	do	do.[3]	5	1.65	27.50	63.66	5.75	1.44	Do.
Do	Genth	do	6	1.16	21.90	70.48	6.46		Do.
Do	Clarke	Clarke [4]	7		24.48	72.44	3.08	.99	Do.
Black Diamond	Battle	Chance [5]	8	4.25	4.91	74.59	14.12	2.13	Anthracite.
Wilcox	Johnson	Emmons [6]	9		8.28	83.12	8.60		Do.
Do	do	do	10		6.64	83.76	9.60		Do.
Do	do	do	11		7.35	87.18	5.47		Do.
Gardner	Battle	Chance [7]	12	1.73	6.38	80.01	9.13	2.75	Do.
Lower bench:									
Farmville	do	do [1]	13	1.29	30.25	55.76	9.82	2.88	Bituminous.
Do	do	do	14	1.50	29.32	57.62	9.22	2.34	Do.
Gulf	Clarke	Clarke [4]	15		24.22	67.86	7.92	1.42	Do.
Gulf:									
Farmville	Battle	Chance [1]	16	2.15	28.88	52.56	12.69	3.72	Do.
Do	do	do	17	1.36	28.71	51.24	14.51	4.18	Do.
Taylor coal pit	Battle	do.[2]	18	1.87	32.78	59.96	4.02	1.37	Do.
Gulf	Clarke	Clarke [4]	19		23.94	66.37	9.69	3.33	Do.

[1] Chance (1885, p. 33–34.
[2] Chance (1885, p. 39).
[3] Chance (1885, p. 42).
[4] Clarke (1887, p. 146).
[5] Chance, (1885, p. 45).
[6] Emmons (1856, p. 252–253).
[7] Chance (1885, p. 47).

Southeast and southwest from the center of thickest coal, near Cumnock, the general thinning of the coal and the increase in number and thickness of shale partings are accompanied by an increase in the content of ash and sulfur and by a decrease in the heating value of the coal. These progressive lateral variations are shown by the average analyses of the main bench of the Cumnock coal bed in five different parts of the field, listed below in geographic order beginning at the northeastern end of the Sanford basin.

Lateral variations in average composition and rank of the main bench of the Cumnock coal bed

Location	Sample No.	Composition of coals "as received" (percent)						Dry mineral-free fixed carbon (percent)	Rank
		Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	B. t. u.		
McIvor mine	A–95555 [1]	2.9	26.4	54.0	16.7	4.9	12,290	70	Medium-volatile bituminous.
Carolina mine	85592 [1]	2.0	32.4	58.1	7.5	2.3	13,810	65	High-volatile B bituminous.
Cumnock mine	85450 [2]	2.5	32.0	57.3	8.2	2.0	13,620	65	Do.
Drill holes between Gulf and Cumnock	Average of 5 analyses	2.6	28.7	55.0	13.7	3.0	12,840	67	High-volatile C bituminous.
Murchison mine	A–95546 [1]	3.1	15.9	60.4	20.6	3.2	11,740	82	Low-volatile bituminous.

[1] Composite of 3 samples.
[2] Composite of 4 samples.

Using the average compositions listed above, the percentage of dry, mineral-free fixed carbon and the rank of the coal at each locality were determined according to procedures established by the American Society for Testing Materials (1938). These are listed in the two columns on the right side of the above table. The coal in the main bench of the Cumnock coal bed ranges in rank from high-volatile C bituminous (between Gulf and Cumnock) to medium-volatile bituminous (at the McIvor mine) and low-volatile bituminous (at the Murchison mine).

It is unfortunate that analyses comparable to those of the bituminous coals have not been made for the anthracite so precise changes in composition could be studied. The basic chemical change in metamorphism of coal to anthracite is a loss of volatile matter, resulting in an increase in the ratio of carbon to oxygen. As metamorphism progresses, this ratio becomes higher, and the rank of the coal changes to semianthracite, anthracite, or meta-anthracite. The partial analyses listed in table 11 suggest that there is a considerable range of compositions among the anthracite coals, reflecting differences in distance from the intrusive and in degree of metamorphism. It is possible that all classifications, of both anthracite and bituminous coals exist in the different coal beds in different parts of the coal field.

The composition of coke (found in a pit near Farmville by Chance) is listed in table 11 (Analysis No. 1). In recent years, analyses have been made of coke from the main bench in drill hole BMDH D–1 (Analysis No. C–24682), and from the top bench in drill hole BMDH D–2, deflected (Analysis No. C–27088). These are listed in table 10. Another analysis of the coke from hole BMDH D–2 (Analysis No. C–23397) is available from a sample cored in the original hole, before it was blocked and deflected. Partial analyses of these three recently examined cokes are listed below, together with analyses of coke from the Richmond basin of Virginia.

Composition of coke from Deep River and Richmond Triassic coal fields on an "as received" basis

Location of sample	Sample No.	Composition (percent)					B. t. u.
		Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
Deep River, BMDH D–1, main bench	C–27088 [1]	6.1	8.3	70.1	15.5	1.1	10,930
Deep River, BMDH D–2 (original), top bench	C–23397 [1]	1.4	14.1	77.6	6.9	1.8	14,040
Deep River, BMDH D–2, (deflected) top bench	C–24682 [1]	2.0	13.8	77.3	6.9	1.8	14,040
Richmond	B–53563 [1]	1.4	14.7	77.6	6.3	1.0	14,450
Do	Average of 9 analyses [2]	1.5	13.1	75.4	9.5	2.1	-------

[1] Analysis by U. S. Bureau of Mines.
[2] Roberts (1928, p. 114).

PHYSICAL PROPERTIES

The bituminous coal in the main bench of the Cumnock coal bed, from the Black Diamond mine to the Carolina mine, is bright and black, and contains few dull bands and almost no shaly partings. Thin sections of this coal from drill holes BMDH D–2, E–2, and DR–2, and from the Carolina mine, have been studied by Bryan Parks (1952). These studies showed that the bright constituents—anthraxylon, composed of woody tissue; and bright attrital coal, composed of anthraxylon with small amounts of dull attritus (plant debris such as spores, cuticles, pollen extines, resins, and waxes)—constitute 90 to 96 percent of the coal. The proportions (given as weight percent) of anthraxylon, bright attrital coal, dull attrital coal, and fusain, as determined by Parks (1952, p. 15–17), are listed below, together with the ash content of each constituent. The total ash content of each specimen before and after gravity (float-and-sink) separation of coal and non-coal ingredients is also shown.

Summary of petrographic data from percentage analyses of core and mine samples of Cumnock coal

[Petrography by Byran Parks]

Constituents	Core sample			Channel sample
	BMDH D–2	BMDH E–2	BMDH DR–2	Carolina mine
Anthraxylon	27.6	47.2	45.3	26.0
Ash content	2.6	1.3	2.3	3.0
Bright attrital coal	63.5	45.5	51.2	69.4
Ash content	6.7	6.6	7.1	6.8
Dull attrital coal	8.9	3.3	3.0	4.6
Ash content	22.3	20.2	17.4	21.7
Fusain	---------	4.0	.5	---------
Ash content	---------	11.2	12.0	---------
Ash content of coal before float-and-sink separation	8.0	9.3	12.2	9.7
Amount of float coal	95.3	89.7	88.3	93.6
Ash content	6.7	4.3	5.9	6.6
Amount of sink coal	4.7	10.3	11.7	6.4
Ash content	49.2	49.5	52.7	53.5

A study of the non-coal sink fraction from the gravity separation of this coal led Parks to conclude that the impurities in the main bench of the Cumnock coal bed consist of bony, high-ash coal (coal mixed with clay minerals of silt size) and mineralized fusain (woody tissue with pyrite, calcite, or kaolinite in pore cavities). These impurities are most abundant through a thickness of 3 to 8 inches in the top and in the bottom of the bench. The physical appearance, constituents, and ash content of different parts of the main bench in the Carolina mine were listed by Parks in table 12.

Coal in the main bench of the Cumnock bed becomes progressively more shaly southeast and southwest of the Gulf-Cumnock area. Shale partings are abundant in the McIvor, Gardner, and Murchison mines. The coal in the top bench generally resembles that in the main bench in the center of the field, but the coals in the lower benches and in the Gulf bed are generally dull, bony, and brownish- or grayish-black.

No fresh exposures of anthracite were observed during this investigation. Fragments of anthracite on the dumps at the Black Diamond and Deep River mines have brownish- to reddish-black color, sub-metallic lustre, and sub-conchoidal fracture. Shaly partings are present, but these specimens probably are not representative of the best coal mined at these places. No coke was observed, but the coke in the Richmond basin, which is probably similar to that in the Deep River field, is described by Roberts as medium-gray to grayish-black, porous, and in general, resembling synthetic coke. J. M. Schopf, of the U. S. Geological Survey Coal Geologic Laboratory, states that thin sections of the coke from drill hole BMDH D–1, which he has examined, are only slightly translucent and are comparable to high-temperature commercial coke, whereas thin sections of the coke from drill hole BMDH D–2 are considerably more translucent and resemble low-temperature commercial coke.

The Deep River coals are cut by smooth, parallel, or nearly parallel, cleavage planes or cleats, probably averaging less than one-fourth of an inch apart and inclined at angles of 60° to 90° to the bedding. Figure 33 shows the cleats in the main bench of the Cumnock coal bed in the Carolina mine. These cleavage fractures are most numerous and most continuous in the bright, low-ash bituminous coals. They are more widely spaced in bony, high-ash coals and are interrupted by bony, or shaly, partings in the coals. As a result, poorer quality coals yield a higher percentage of lump and a higher percentage of core recovery than do the higher quality coals. The cleats in anthracite specimens have been observed to be generally from one-fourth to one-half inch apart. Transverse cleats are

TABLE 12.—*Petrographic composition of main bench of Cumnock coal bed in Carolina mine*

[Petrography by Byran Parks]

Description		Thickness (inches)	Ash (percent)	Petrographic composition (percent)				
Hard, compact, dark-gray, siltstone with some very fine streaks of coal. Not cleated.		4	73.7	10 percent coal, 90 percent mineral matter. (Not sectioned).				
				Anthraxylon	Translucent attritus	Opaque attritus	Fusain	Mineral matter
Bright, finely banded coal marked by a prominent set of vertical cleats spaced approximately ½ inch apart. Coal is very friable and tends to break in thin slabs and splintery fragments.	Friable coal of grayish-black luster	8	16.7	53.0	31.8	0.2	0.7	14.3
	Very friable coal of brilliant black luster	14	5.2	71.9	26.3	0.7	0.1	1.0
	Extremely friable coal of bright black luster	13	10.6	(Due to extremely fractured condition of the coal, no sample suitable for making thin sections could be recovered from this portion of the bed. The petrographic composition of this layer is probably similar to layer above.)				
Very finely laminated grayish, dull lustered coal. Vertical cleats are less numerous than in layers 1, 2, and 3, and coal is much less friable. Tends to break in thick slab-like fragments. High ash content classifies this as a bony coal		5	28.3	9	65.6	0.9	0.5	24
Dark-gray silty shale		6	------	------	------	------	------	------

rare in the bituminous coals, but they are abundant in the anthracites. The trends, origin, and significance of fractures in the Deep River coals have been discussed in the chapter on the structure of the Deep River field.

Specific gravities of Deep River bituminous coal range from 1.32 to 1.72, specific gravities of anthracite range from 1.47 to 1.56, and specific gravities of coke range from 1.43 to 1.94. The available data show that, in general, the specific gravity increases with the increase in rank of the coal. In the bituminous beds, it increases as the quality and heating value decrease; this is due, in part, to an increase in the ash content. The specific gravities of these coals are listed below; those for anthracite were computed from weights of coal published by Chance, and the others were supplied by the Bureau of Mines.

Specific gravity of coals from the Deep River coal field

Location of sample	Bituminous coal				Anthracite coal	Coke	
	Top bench	Main bench	Lower benches	Gulf bed	Main bench	Top bench	Main bench
BMDH D-1	------	------	1.45	1.43	------	------	1.94
BMDH D-2	------	1.39	------	------	------	1.44 1.43	------
BMDH E-1	------	1.39	1.38 1.51	1.45	------	------	------
BMDH E-2	------	1.40	1.62	------	------	------	------
BMDH 2	------	------	1.47	1.33	------	------	------
BMDH DR-1	------	1.43	------	1.72	------	------	------
BMDH DR-2	1.32	1.45	------	------	------	------	------
Black Diamond mine	------	------	------	------	1.56	------	------
Wilcox pit	------	------	------	------	1.49	------	------
Gardner mine	------	------	------	------	1.47	------	------
Averages by coal bench	1.32	1.41	1.49	1.48	1.51	1.44	1.94
Averages by rank	1.45				1.51	1.60	

UTILITY

The commercial value of the bituminous coal in the main bench of the Cumnock coal bed has been established by its use in locomotives and stationary steam plants, in heating plants of schools, hotels, office buildings, and homes, in brick kilns, and recently in the steam power plant of the Carolina Power and Light Company, south of Moncure. Heating values of the best coal in this bench are only slightly lower than those of competing coals from Virginia, West Virginia, and Tennessee. Heating values of the poorer coal in this bench at the Murchison and McIvor mines are considerably lower. Although a small quantity of coal from these mines has been used successfully to heat buildings and homes, it is not so well suited for large-scale industrial use as the coal near Cumnock and Gulf.

The sulfur content of the best Deep River coal averages 2 to 3 percent, as compared to an average of 1.1 percent for the competing coals. This relatively greater content of sulfur probably has little effect on the firing and heating characteristics of the Cumnock coal, but it makes this coal a little more corrosive to grates. To keep the sulfur content of the commercial coal as low as possible, it is desirable to eliminate pyrite nodules during mining. However, pyrite nodules are not abundant in this coal, except locally, and they do not account for the high percentages of sulfur shown by the analyses because nodules were excluded from the samples before they were analyzed. The relatively high sulfur content is caused mainly by finely disseminated pyrite. In an attempt to lower this sulfur content, samples of the coal were subjected to beneficiation tests at the U. S. Bureau of Mines plant in Urbana, Ill. It was found that the original sulfur content of 2.32 percent could be reduced to 1.76 percent by float and sink methods, to 1.85 percent by washing in a jig, and to 1.82 percent by washing on tables. This reduction was considered insufficient to justify the expense. The report of the Bureau of Mines, quoted by Campbell and Kimball (1923, p. 89–90), explains the failure to greatly reduce the sulfur content, as follows:

The general sample representing the entire lot of coal contained 1.52 per cent of pyritic sulphur and 0.80 per cent of organic sulphur. The total sulphur content amounted to 2.32 per cent, of which 34.5 per cent was present as organic sulphur and 65.5 per cent as pyritic sulphur. Sulphate sulphur was not determined as the analysis made at the Pittsburgh station of the mine samples showed a maximum value of only 0.026 per cent * * * This condition is favorable for a good sulphur reduction, but it is counterbalanced by the finely disseminated nature of the pyritic sulphur present in the coal.

Tests made at the U. S. Bureau of Mines Experiment Station in Pittsburgh, which were mentioned in the preceding quotation, show that metallurgical coke can be made from the coal in the main bench of the Cumnock coal bed. A large sample of washed coal from the Cumnock mine was tested to determine its coking properties and related by-products. The compositions of the coal and the coke and the results of the experiment are listed by Campbell and Kimball (1923, p. 87), as follows:

Proximate and ultimate analyses (in percent) of washed coal and coke

	Proximate analysis				Ultimate analysis					
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	B. t. u.
Coal	1.0	33.0	59.6	6.4	5.2	78.9	2.1	5.8	1.6	14,220
Coke	.5	3.8	87.2	8.5	1.2	86.0	2.0	1.0	1.3	13,350

The results of laboratory coking tests on washed coal were as follows:

Final coking temperatures	775° to 800° C.
Weight of charge	15 pounds.
Coke yield	75 percent of charge.
Gas yield	8,000 cu ft per ton of coal.
Ammonium sulphate	23 pounds per ton of coal.
Tar (dehydrated)	13.9 percent of coal charged or 22 gallons per ton.

Concerning the above test, the report by the Bureau of Mines stated:

The by-product yield of this coal is entirely satisfactory and compares favorably with yields from Freeport, Pa. coal. It is felt that with a full coking temperature (950° C.) and 18 hours time, it would be reasonable to expect a 70 percent yield of metallurgical coke, 10,000 to 12,000 cubic feet of good gas, 11 gallons of tar, and 25 to 27 pounds of ammonium sulphate. In general, the coke, as far as it can be judged by a laboratory scale test, is of very good quality fully equal in all respects to Freeport or Pittsburgh cokes. The sulphur in the coke is somewhat high (1.3 percent), but this could be cut down by admixture of a low-sulphur steam coal. Such a mixture of coal is now considered to be good by-product practice.

This test establishes the coking quality of the Deep River coal. Vilbrandt (1927a, p. 129) also tested the coking properties of this coal and determined the composition of coke residues at different temperatures, as follows:

Analyses of coke still residues (in percent) of Deep River coal

[By F. C. Vilbrandt]

Temperature (centigrade)	Volatile matter	Fixed carbon	Ash	Sulfur	B. t. u.
Original coal	37.80	51.95	9.03	0.22	14,330
200°	26.82	63.71	9.25	.22	14,280
300°	8.95	81.70	9.31	.04	14,210
360°	3.40	86.77	9.80	.03	14,130
420°	2.53	87.39	10.05	.03	14,090
480°	1.61	88.07	10.29	.03	14,060
540°	.93	89.03	10.02	.03	14,050
600°	.37	89.14	10.49		14,030
660°	.12	89.11	10.77		14,000

Campbell and Kimball suggested that although there may be little demand for coke in North Carolina, except possibly for domestic use as a substitute for anthracite, the ammonium sulphate by-product of the coking operation might be of great value for use in fertilizers. The possibility of obtaining other byproducts—producer gas, solvent light oils, benzol, and tars for dyes, roofing, and road materials—is suggested by Vilbrandt. The quantity and importance of by-products obtainable from Deep River coals should be thoroughly investigated. Such products might be of great value to local industry and agriculture, and a by-product industry would stimulate coal mining. If valuable by-products could be obtained in important quantity from the poorer coals (such as those in the lower benches of the Cumnock coal bed) it might be profitable to mine coals that otherwise would remain unexploited.

The lower benches of the Cumnock coal bed generally are separated from the main bench by 18 to 24 inches of shale or blackband, and they could easily be mined with the main bench. In the early history of the Cumnock mine, coal from these benches was mined and mixed with coal from the main bench, but the resulting product was not salable. Analyses listed in table 10 show that coals from the lower benches are too high in ash content to be commercially important unless some method can be found to reduce it. Beneficiation tests were made at the U. S. Bureau of Mines laboratory in Urbana, Ill., on a

1,150 pound sample of coal from the lower bench in the Carolina mine. The report of the Bureau of Mines, quoted by Campbell and Kimball (1923, p. 88–89), is as follows:

> The sample of coal received at the laboratory representing the bottom bench of the Cumnock bed from the Farmville (Carolina Coal Company's) mine, consists very largely of bony coal and carbonaceous shale. Only a small amount of coal low in ash content is present. It is, therefore, impossible to treat this coal successfully by the usual coal-washing methods to secure a reasonable yield of coal as low in ash content as the coal of the top [main] bench (8 to 10 percent of the bed). The treatment of this coal at ¼-inch minimum size on either jigs or tables would probably yield 50 to 70 percent of washed coal with an ash content in the neighborhood of 24 percent.

Additional attempts were made to reduce the ash content of the lower-bench coal by the Trent process, wherein pulverized, moistened coal is treated with oil, which forms an "amalgam" with the carbon of the coal and allows the earthy matter to fall to the bottom of the tank. The results of this test are summarized by Campbell and Kimball (1923, p. 90) as follows:

> If the coal were treated by this process, the result would be the so-called amalgam which contains about 21.6 percent of fuel oil in addition to the finely divided carbon and ash, or if the oil were distilled it would leave only the finely divided carbon and ash. In either form the product can be used as a fuel—if in the amalgam form with a content of ash of 13.4 percent and if in the form of dry purified coal with an ash content of 17.1 percent.
>
> The reduction of the ash by this process is rather disappointing and is said to be due to the fact that the earthy material is present in a very finely divided condition and this means that to reach the carbon itself, the crushing would have to be possibly to 200 mesh which would be quite expensive.

Although the Trent process reduced the ash content from 27.2 percent in the original coal to 17.1 percent in the dry purified coal, the cost of the process may exceed the value of the product obtained. If ammonium sulphate or some other valuable product could be extracted from the residue of such a process of beneficiation, use of the process might be profitable.

The problem of uses and markets for the Deep River coals is complex because the properties of the coals in the different benches and in different parts of the field are not similar. There is a proven market and a variety of possible uses for the best bituminous coal in the main bench of the Cumnock coal bed. For the poorer bituminous coal in this, and in the other coal benches, there is little market at present, and only by means of additional research in beneficiation and extraction of by-products will it be possible to determine if they can be made to yield products of economic value and whether they can be mined profitably on a large scale. A local market doubtless exists for the anthracite because producers have had no trouble selling their product in the past. Additional analytical work is needed to determine the true value of the anthracite.

MINING CONDITIONS

From Cumnock to Carbonton the numerous faults, folds, and intrusions in the coal between the Gulf fault and the coal outcrop make large-scale mining economically impossible at the present time. Between Carbonton and Glendon conditions are similar to those in the complexly folded, faulted, and intruded area northwest of the Deep River fault. Some of the coal in these areas could be mined profitably if the price of coal increased sufficiently, but no more than a third could be extracted profitably even under the most favorable market conditions.

The future of the Deep River coal field is in the development of the coal in the block between the Gulf and Deep River faults. In this part of the field, large sub-blocks between cross faults contain coal averaging about 36 inches in thickness. Most of this coal has an average inclination of less than 15° and is relatively unaffected by faulting and intrusives, except near the cross faults shown on plate 7. The change in strike of the beds, and the warping and cross faulting related to the nearby junction of the Gulf and the Deep River faults, present mining problems in the Cumnock-Carolina mine area that are more complicated than should be encountered in the more simple structure farther to the west. In the complex zone of faults and dikes half a mile west of Cumnock, the coal probably is not minable. The best mining conditions in the field should be found west of this zone.

The coal is flatter and nearer the surface south of the Deep River fault than it is north of the fault. For reasons previously stated, however, it is believed that not much of the coal in this part of the field is more than 2 feet thick. Although the McIvor and Gardner mines succeeded in working coal less than 2 feet thick on a small scale, it is unlikely that large-scale mining of such thin coal would be successful in an area of numerous faults and intrusives, such as the Deep River field. Any attempts to mine the coal south of the Deep River fault should be preceded by diamond drilling to determine if the coal in this part of the field is thick enough and if the quality of the coal is high enough to justify the expense of opening a mine.

The cost of mining the relatively thin, structurally complicated coal in the Deep River field is higher than mining costs in competing fields of Virginia, West Virginia, and Kentucky. However, this disadvantage is offset by the fact that the cost of shipping Deep River coal to markets in North Carolina is considerably less than shipping costs from out-of-state fields. In a report prepared for the State of North Carolina in 1943, Morfit (1943, p. 28–30) estimated a potential market for 3 million tons of coal per year within a radius of 150 miles of the Deep River field, with a freight differential ranging from $1.24 to $2.41 per ton in favor of the Deep River coal. Past mine failures and the resultant poor reputation of the Deep River coal field have been caused, to a large extent, by the poor structural location of most of the mines. With a large local market and a shipping cost advantage, future mining in this field should be successful if the mine operations are planned to fit the geological conditions.

RESERVES

Estimated reserves of coal in the Deep River coal field are tabulated in table 13. These estimates include only the coal in the main bench of the Cumnock coal bed and in the Gulf coal bed; they do not include the coal in the top bench or lower benches of the Cumnock bed. The computations are limited to coal at least 14 inches thick and less than 3,000 feet below the surface. For the purpose of these calculations, the southeastern limit of coal in the Cumnock bed forms a line trending S. 40° W. from a point on the coal outcrop three-fourths of a mile east of the McIvor mine. The southwestern limit forms a line trending S. 55° E. from a point on the coal outcrop three-fourths of a mile south of the Gardner mine. The southern limit forms an east-west line across the Sanford basin, west of Sanford. These limits are shown in figure 39. Reserve tonnage computations for the Cumnock bed include the entire area northward from these lines to the coal outcrop, except for a narrow area bordering the north side of the Deep River fault where the coal is more than 3,000 feet below the surface. Coal, at least 14 inches thick, in the Gulf bed is confined to an area between the coal outcrop and the 2,000-foot cover line, extending from Gulf to the Carolina mine.

The reserves listed in table 13 are classed as "measured" where the tonnages are computed from dimensions revealed in drill holes, mine workings, and outcrops; as "indicated" where the tonnages are computed partly from specific measurements and partly from projections of visible data; and as "inferred" where computations are based entirely on geologic evidence without benefit of actual measurements. The distribution of "measured," "indicated," and "inferred" reserves of coal in the Cumnock coal bed is shown in figure 39. North of the Deep River fault, all coal in the Cumnock bed within a fourth of a mile of each drill hole that penetrated minable coal is classed as "measured." Also classed as "measured" is all coal in this bed within a belt half a mile wide that borders the

TABLE 13.—*Reserves of coal in the Deep River coal field, Chatham, Lee, and Moore Counties, North Carolina*

[In thousands of short tons]

Bed, reserve class, and overburden	Range in thickness (inches)	Area (acres)	Estimated original reserves	Mined and lost in mining, Jan. 1, 1950	Remaining reserves, Jan. 1, 1950	Recoverable reserves, Jan. 1, 1950 (assuming 50 percent recovery)
Cumnock:						
Measured:						
0–2,000	>36	3,494	20,934	1,574	[1] 19,360	9,680
	28–36	2,483	9,037	15	9,022	4,511
	14–28	770	2,399	31	2,368	1,184
2,000–3,000	>36	199	1,183	0	1,183	592
	28–36	149	805	0	805	402
Indicated:						
0–2,000	>36	1,136	6,787	0	6,786	3,393
	28–36	813	3,863	0	3,863	1,932
	14–28	6,921	20,328	0	20,328	10,164
2,000–3,000	>36	1,265	7,302	0	7,302	3,651
	28–36	1,090	4,923	0	4,923	2,462
	14–28	494	2,055	0	2,055	1,027
Inferred: 0–2,000	14–28	8,195	22,373	0	22,373	11,187
Total			101,989	1,620	100,368	50,185
Gulf:						
Measured: 0–2,000	14–28	1,767	5,306	1	5,305	2,653
Indicated: 0–2,000	14–28	2,065	4,664	0	4,664	2,332
Total			9,970	1	9,969	4,985
Grand total			111,959	1,621	110,337	55,170
Total in beds:						
36 inches or more			36,206	1,574	[1] 34,631	17,316
28–36 inches			18,628	15	18,613	9,307
14–28 inches			57,125	32	57,093	28,547

[1] Includes 8,469 thousand tons averaging 42 inches in thickness.

coal outcrop from a fourth of a mile south of the Black Diamond mine northeastward to the Deep River fault, as well as an area half a mile square surrounding the Murchison mine.

All other coal in the Cumnock bed north of the Deep River fault and less than 3,000 feet below the surface is classed as "indicated." South of this fault, areas half a mile square, surrounding both Gardner and McIvor mines, contain coal that is classed as "measured." The remaining coal within a belt 2 miles wide along each of the two coal outcrops south of the Deep River fault is classed as "indicated," and the coal in the center of the field south of the fault, between the areas of "indicated" coal, is listed as "inferred." In the Gulf bed, coal classed as "measured" underlies about half of areas 1, 2, 4, and 6 (as shown in fig. 39), and coal classed as "indicated" underlies half of areas 1, 2, 4, 6, and 8.

Average thicknesses of coal used in calculating the "original reserves" are 2 or 3 inches less than average thicknesses of beds shown by the coal thickness patterns on plate 7. One or 2 inches of coal at the top and the bottom of the beds are commonly bony coals, relatively high in ash, that should be removed from the coal before it is sold. Therefore, this material is not included in the reserve estimates.

In computing the "original reserves," estimates were made of the percentage of coal converted to semianthracite, to anthracite, and to coke by the diabase intrusives. The computations were made on a basis of 2,000 tons (of 2,000 pounds each) per acre foot for semianthracite, anthracite, and coke, and 1,800 tons per acre foot for bituminous coal. About 16 percent of the reserve tonnage of "measured" coal, 22 percent of the reserve tonnage of "indicated" coal, and 17 percent of the reserve tonnage of "inferred" coal is estimated to be metamorphosed to a rank higher than bituminous. These percentages are regarded as minimum values and will probably be changed considerably as additional knowledge of the subsurface distribution of intrusives is obtained. The average thickness of coal used in these calculations, and the estimated original reserves of metamorphosed and non-metamorphosed coal in the areas shown in figure 39 are as follows:

Thickness and original reserves of coal by areas

Beds	Area No.	Thickness (inches)	Estimated original reserves (thousands of short tons)		
			Bituminous	Anthracite and coke	Total
Cumnock	1	36	5, 368	----------	5, 368
	2	42	5, 796	64	5, 860
	3	28	3, 881	228	4, 109
	4	32	3, 215	396	3, 611
	5	36	805	----------	805
	6	40	5, 121	58	5, 179
	7	32	2, 869	----------	2, 869
	8	42	3, 573	210	3, 783
	9	40	1, 183	----------	1, 183
	10	38	2, 255	278	2, 533
	11	40	6, 412	374	6, 786
	12	38	7, 142	160	7, 302
	13	30	839	2, 798	3, 637
	14	20	243	808	1, 051
	15a	30	1, 829	2, 034	3, 863
	15b	21	3, 841	4, 266	8, 107
	16	21	236	260	496
	17	15	117	130	247
	18	18	202	224	426
	19	18	7, 620	940	8, 560
	20	18	19, 915	2, 458	22, 373
	21	18	2, 855	560	3, 415
	22	18	202	224	426
	Total Cumnock bed		85, 519	16, 470	101, 989
Gulf	1 (part)	18	1, 343	----------	1, 343
	1 (part)	15	1, 118	----------	1, 118
	2	15	2, 066	24	2, 090
	4 (part)	24	1, 202	148	1, 350
	4 (part)	15	752	92	844
	6 (part)	24	1, 552	16	1, 568
	6 (part)	15	972	10	982
	8 (part)	15	637	38	675
	Total Gulf bed		9, 642	328	9, 970
Grand total			95, 161	16, 798	111, 959

From the tonnage of "original reserves" the estimates of present "recoverable reserves" are obtained by first subtracting the tonnages of coal "mined out and lost in mining", which include coal left as pillars, coal that adjoins or is isolated by caved and flooded mine workings (therefore not minable), and coal that has been mined. Of the resulting tonnages (listed in table 13 as "remaining reserves"), 50 percent are calculated as "recoverable reserves." It is estimated that the remaining 50 percent will be unminable because of faulting, metamorphism, or irregularities in the beds, or that it will be lost in mining. The percentage of "recoverable" coal may be lower where the beds are badly faulted and metamorphosed, and it may be higher where the beds are not disturbed. It is believed that the estimates of reserves of recoverable coal listed as "measured" are accurate to within 15 percent.

In 1923, Campbell and Kimball (p. 79) estimated the total original reserves in the Cumnock coal bed to be 84,960,000 short tons. Later, Campbell reduced the estimate of the original tonnage in the Cumnock bed to 68,000,000 short tons, and this figure has been widely quoted in the interest of conservatism as the total original coal reserves of North Carolina. On the basis of the present survey, the total original reserves in the Cumnock bed is estimated to be 101,989,000 short tons (see table 13). This figure is not directly comparable with the original estimate because Campbell and Kimball included no coal deeper than 2,000 feet below the surface and none of the coal in the area south of the Deep River fault, whereas the estimate in table 13 includes coal to a depth of 3,000 feet and covers a large area south of the Deep River fault where the coal is now believed to be 2,000 feet or less below the surface. An examination of the detailed tabulation of the reserves contained in table 13, however, will show that, when allowance is made for the difference in the bases selected, the estimate of original reserves by Campbell and Kimball is essentially comparable to the present estimate.

Campbell and Kimball estimated that 80 percent of the original reserves are recoverable. It is now believed that only 50 percent of the coal in the Deep River field can be recovered, and, therefore, the estimate of recoverable reserves in the Cumnock coal bed, shown in table 13, is 50,185,000 tons. Thus, although present evidence suggests that there is a greater total reserve of coal in the Deep River field than was formerly realized, the recoverable reserve of thick coal is smaller.

A preliminary estimate of the coal reserves in the Deep River coal field was made by the writer in 1949 (Reinemund, 1949, sheet 2, table 1). The total original reserve of coal in the Cumnock and Gulf coal beds was estimated at that time to be 110,462,000 short tons. Recalculations of these reserve estimates have subsequently been made using information from mine workings and drill holes that was not available in 1949. The revised estimate of total original reserves of coal in the Cum-

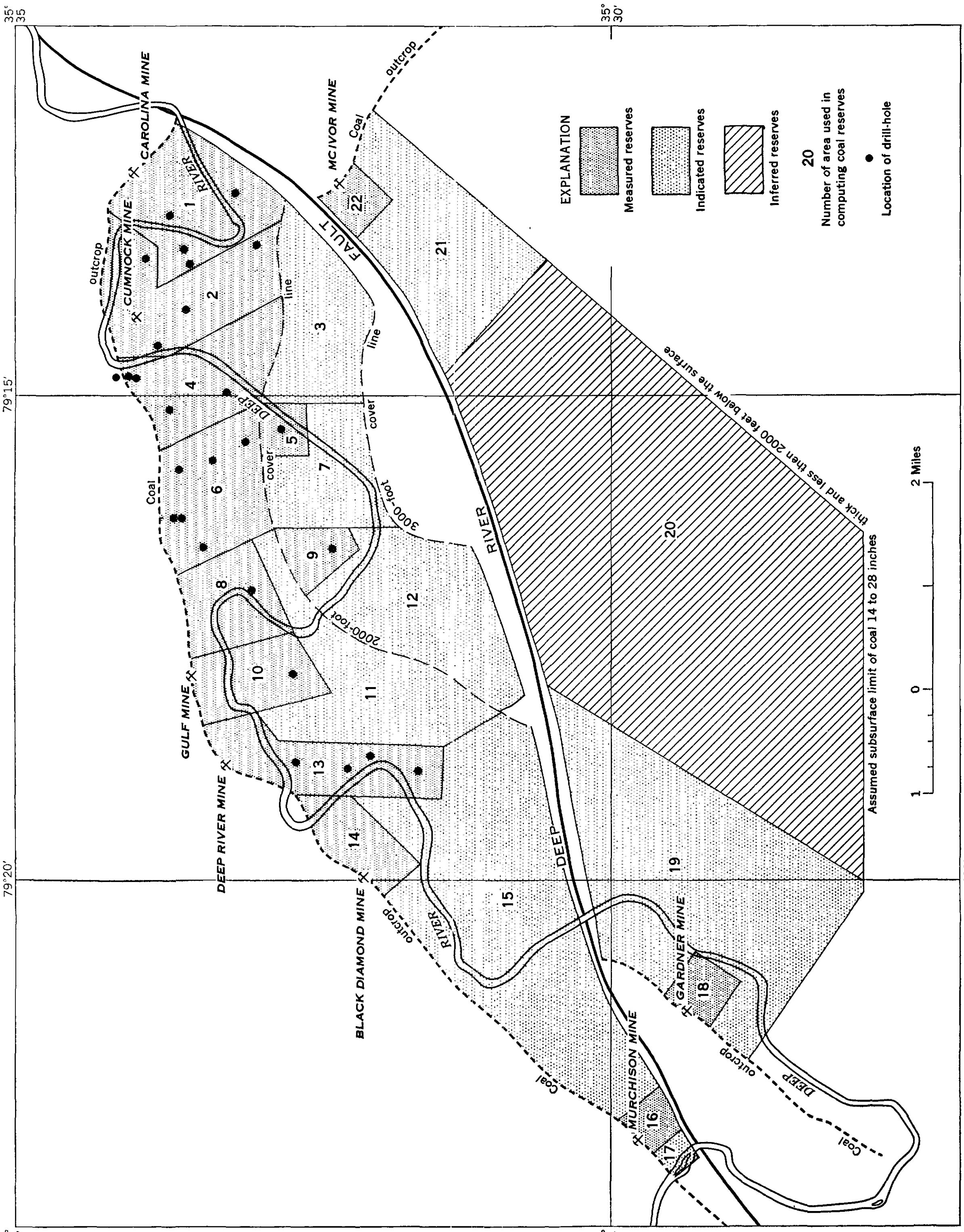


FIGURE 39.—Map showing distribution of "measured," "indicated," and "inferred" reserves in the Cumnock coal bed.

nock and Gulf beds, listed in table 13, is 111,959,000 short tons, of which 55,170,000 short tons is calculated as the total recoverable reserve of coal in the Deep River field.

BLACK SHALE AND BLACKBAND

OIL SHALE

Beds of black shale and blackband in the Cumnock formation contain organic material, known as kerogen, which is partly converted to shale oil when heated in a retort to temperatures above 400° C. It is necessary to crush and heat the shale or blackband in a closed system to convert the kerogen to gas and oil. The kerogen in these beds does not yield oil at ordinary temperatures; however, some of the shale in the upper part of the Cumnock formation (which has the highest content of kerogen) may have small drops of oil in interstices or on fresh surfaces, and it may emit small amounts of gas when penetrated by drill holes.

About 100 years ago, several tons of black shale from the Cumnock formation were quarried a fourth of a mile southwest of the Gulf mine and were shipped to Scotland for extraction tests of the oil content, but no use was made of the information thus obtained. In 1927, samples of black shale and blackband from the Cumnock formation were collected at the Cumnock mine and were analyzed by Vilbrandt (1927). Recomputations based on the oil content of these beds, as listed in table 6 of his report (1927), show that three separate beds of black shale in the upper part of the Cumnock formation (having thicknesses of 7, 32, and 38 feet) yield shale oil in amounts, respectively, of 8.4, 9.8, and 12.7 gallons per ton of shale; that blackband beds associated with the Cumnock coal bed (totaling 29 inches in thickness) yield 3.6 gallons per ton; and that blackband beds associated with the Gulf coal bed (totaling 50 inches in thickness) yield 6.9 gallons per ton. The stratigraphic positions of beds sampled and analyzed by Vilbrandt are shown on the drill record of diamond-drill hole DH–1 (see Appendix). The oil contents, together with the ammonium sulphate, gas, moisture, carbon, and ash contents of each sample analyzed by Vilbrandt, and the heating value of the gases evolved during the distillation of the oil, are listed below in table 14.

TABLE 14.—*Analyses and products of distillation of shale and blackband from the Cumnock formation*[1]

Location and sample no. of beds	Thickness of beds (feet)	Analysis of the rock			Products of distillation				
		Moisture (percent)	Fixed carbon (percent)	Ash (percent)	Spentshale (lbs. per ton)	Shale oil (gal. per ton)	Ammonium sulphate $(NH_4)_2SO_4$ (lbs. per ton)	Gas (cu. ft. per ton)	B. t. u. of evolved gas
Black shale above Cumnock coal bed:									
0–1	7	0.36	27.29	72.35	1,689	8.4	8.0	1,760	151
0–2	32	.48	28.57	70.95	1,689	9.8	9.5	1,347	222
0–3	8	1.03	35.13	63.84	1,579	12.7	12.4	2,940	269
Blackband beds with Cumnock coal bed:									
0–4	2.5	.85	27.33	71.80	1,535	3.6	10.8	734	----------
Blackband beds with Gulf coal bed:									
0–5	4.2	1.42	24.43	74.05	1,777	6.9	8.3	3,260	301

[1] Compiled from data published by Vilbrandt (1927, p. 17, 21). Oil analyses recomputed from data on p. 17 of Vilbrandt's report.

In 1950, nine core and channel samples of black shale and blackband from the Deep River coal field were tested by the U. S. Geological Survey in an attempt to obtain additional information on the oil contents of these beds. Samples 0–6 and 0–7 were from blackband beds associated with the Cumnock and Gulf coal beds, respectively, in the Carolina mine. The locations of these samples are shown on plate 6. Samples 0–8 and 0–9 were from black shale and blackband above the Cumnock coal bed in drill hole BMDH DR–1, and samples 0–10, 0–11, 0–12, and 0–13 were from blackband beds associated with the Cumnock coal bed in hole BMDH DR–2. The strata included in these samples are shown on the drill records of these holes (see Appendix). Sample 0–14 was from blackband below the main bench of the Cumnock coal bed at the Gulf mine. The oil content of the black shales above the Cumnock coal bed ranged from 1.2 to 2.2 gallons per ton, the oil content of the blackband associated with the Cumnock coal bed ranged from a trace to 15.9 gallons per ton, and the oil content of the blackband associated with the Gulf coal bed was 14.9 gallons per ton.

Oil contents of all samples of shale and blackband in the Deep River area are listed in table 15. These analyses show that although certain beds yield as much as 15 gallons of oil per ton in some parts of the Deep River coal field, the same beds yield very little oil in other and adjacent parts of the field. The average oil yield of these rocks is less than 10 gallons per ton and less than 2,000 barrels per acre, which was considered by Winchester (1928) to be the minimum yield for minable shale in the eastern United States. These rocks yield considerably less oil than the Colorado oil shales (dem-

TABLE 15.—*Content of oil in shale and blackband in the Deep River coal field*

Bed	Samples from Cumnock mine [1]			Samples from Carolina mine [2]			Samples from drill holes BMDH DR–1 and DR–2 [2]			Sample from Gulf mine [2]		
	Sample No.	Thickness (feet)	Oil content (gal. per ton)	Sample No.	Thickness (feet)	Oil content (gal. per ton)	Sample No.	Thickness (feet)	Oil content (gal. per ton)	Sample No.	Thickness (feet)	Oil content (gal. per ton)
Beds above Cumnock coal bed	0–1 0–2 0–3	7 32 8	8.4 9.8 12.7	----------	----------	----------	0–8 0–9	12 4	1.2 2.2	----------	----------	----------
Beds near Cumnock coal bed	0–4	2.5	3.6	0–6	1.7	15.9	0–10 0–11 0–12 0–13	12 1.5 2.8 1.5	1.1 Trace Trace Trace	0–14	2	1.1
Beds near Gulf coal bed	0–5	4.2	6.9	0–7	1.5	14.9	----------	----------	----------	----------	----------	----------

[1] Analyses by Vilbrandt (1927, pp. 17, 21).
[2] Analyses by U. S. Geological Survey.

onstrated by the U. S. Bureau of Mines to be a source of commercial quantities of oil).

The low content of oil in the shales of the Deep River coal field makes it improbable that they can be profitably mined solely to recover the shale oil. Table 18 shows the estimated reserve of shale oil (assuming the beds have an average oil content of 3.5 gallons per ton) in blackband beds immediately above, and below, the Cumnock coal bed. Part of these blackband beds have been removed to gain head room in mining the coal; possibly, they might yield other valuable by-products.

SHALE AND BLACKBAND FOR USE IN FERTILIZER

In addition to modest oil contents, the shale and blackband in the Cumnock formation contain ammonium sulphate $(NH_4)_2SO_4$ and calcium phosphate $Ca_3(PO_4)_2$ in fairly large quantities. Nearly 100,000 tons of black shale and blackband, from beds immediately above and below the Cumnock coal bed, have been taken from the Carolina, Cumnock, Deep River, and Murchison mines and have been sold to various fertilizer manufacturers. Local residents, likewise, have used material from the old mine dumps to increase the fertility of their soil.

In 1928, samples of the shale and blackband of the Cumnock formation, collected in the Cumnock mine, were analyzed by Murphy and Vilbrandt (1930). They found that some beds of black shale (totaling 287 feet in thickness) in the upper part of the Cumnock formation contain 11.2 to 40.8 pounds of $Ca_3(PO_4)_2$ and 31.8 to 72.8 pounds of $(NH_4)_2SO_4$ per ton of shale. The blackband beds (totaling 43 inches in thickness) associated with the Cumnock coal bed were found to contain 26.0 to 297.4 pounds of $Ca_3(PO_4)_2$ and 32.8 to 61.0 pounds of $(NH_4)_2SO_4$ per ton; the blackband beds (totaling 50 inches in thickness) associated with the Gulf coal bed were found to contain 135.4 to 314.6 pounds of $Ca_3(PO_4)_2$ and as much as 46.8 pounds of $(NH_4)_2SO_4$ per ton.

To gain additional information on the quantities of ammonium sulfate and calcium phosphate in these rocks, samples of shale and blackband were collected in 1949 in the Carolina and Gulf mines and from drill holes BMDH DR–1 and DR–2. Tests of these samples by the U. S. Department of Agriculture and by the U. S. Geological Survey showed that beds near the Cumnock coal bed contain 22.2 to 70.6 pounds of $(NH_4)_2SO_4$ and 1.4 to 31.0 pounds of $Ca_3(PO_4)_2$ per ton of rock, and beds near the Gulf coal bed contain as much as 60.6 pounds of $(NH_4)_2SO_4$ and as much as 24.4 pounds of $Ca_3(PO_4)_2$ per ton of rock. These analyses, together with those published by Murphy and Vilbrandt, are listed in table 16. Locations of beds analyzed by Murphy and Vilbrandt are shown on the record of drill hole DH–1, and the locations of analyses from holes BMDH DR–1 and DR–2 are shown on the records of these holes (see Appendix).

Analyses listed in table 16 show the presence of between 30 and 60 pounds per ton of $(NH_4)_2 SO_4$ in most of the rocks tested, and they show that, although there are variations, the contents of $(NH_4)_2 SO_4$ in the samples tested in 1949 do not differ significantly from the contents determined by Murphy and Vilbrandt. The contents of $Ca_3(PO_4)_2$ in the recently analyzed samples average about 20 pounds per ton of rock, only a fifth to a tenth as much as the contents of $Ca_3(PO_4)_2$ in samples tested by Murphy and Vilbrandt. These differences may represent actual lateral variations in content of $Ca_3(PO_4)_2$, but because of the great differences, it seems more probable that they are a result of different methods of sampling or analyzing. Regardless of the cause of the observed difference in composition of the samples, it is apparent from the analyses in table 16 that the average content of $Ca_3(PO_4)_2$ in beds near the Deep River coals is considerably less than was originally indicated.

Estimated reserves of $(NH_4)_2 SO_4$ and $Ca_3(PO_4)_2$ north of the Deep River fault are listed in table 17. These estimates take into account the probable lateral variations in content of these compounds and variations in thickness of the shale and blackband beds. The

TABLE 16.—*Content of nitrogen and phosphorus in beds of shale and blackband in the Deep River coal field*

Beds and sample no.	Nitrogen			Phosphorus		
	Organic nitrogen (percent)	$(NH_4)_2SO_4$ (percent)	$(NH_4)_2SO_4$ (lbs. per ton of shale)	P_2O_5 (percent)	$Ca_3(PO_4)_2$ (percent)	$Ca_3(PO_4)_2$ (pounds per ton of shale)
Samples from Cumnock mine [1]						
Above Cumnock coal bed:						
N-1	0.41	1.59	31.8	0.79	1.73	34.6
N-2	.48	1.87	37.4	.61	1.36	27.2
N-3	.77	3.31	66.2	.58	1.27	25.4
N-4	.48	1.87	37.4	.26	.56	11.2
N-5	.94	3.64	72.8	.96	2.04	40.8
Near Cumnock coal bed:						
N-6	.73	3.05	61.0	.59	1.30	26.0
N-7	.56	2.19	43.8	6.80	14.87	297.4
N-8	.42	1.64	32.8	1.86	4.07	81.4
N-9	.65	2.53	50.6	3.35	7.13	142.6
Near Gulf coal bed:						
N-10	.60	2.34	46.8	7.20	15.73	314.6
N-11	.60	2.34	46.8	3.10	6.77	135.4
Samples from Carolina mine [2]						
Near Cumnock coal bed: N-12	.66	3.09	61.8	.71	1.55	31.0
Near Gulf coal bed: N-13	.64	3.03	60.6	.56	1.22	24.4
Samples from drill holes BMDH DR-1 and DR-2 [3]						
Above Cumnock coal bed: N-14	.24	1.12	22.4	1.97	4.29	85.8
Near Cumnock coal bed:						
N-15	.48	2.25	45.0	.47	1.03	20.6
N-16	.56	2.64	52.8	.03	.07	1.4
N-17	.52	2.46	49.2	.49	1.07	21.4
N-18	.24	1.11	22.2	.39	.85	17.0
Sample from Gulf mine [2]						
Near Cumnock coal bed: N-19	.75	3.53	70.6	.61	1.34	26.8

[1] Analyses from Murphy and Vilbrandt (1930, p. 70); nitrogen content of samples from Cumnock mine given as NH_3.
[2] Analyses by U. S. Dept. of Agriculture.
[3] Sample N-14 from hole BMDH DR-1, analyzed by U. S. Geol. Survey. Samples N-15 to N-18 from hole BMDH DR-2, analyzed by U. S. Dept of Agriculture.

total recoverable reserve of black shale and blackband (as rock) north of the Deep River fault (assuming 65 percent recovery) is estimated to be 3,555,824,000 short tons, containing 74,561,000 short tons of $(NH_4)_2SO_4$ and 31,042,000 short tons of $Ca_3(PO_4)_2$. These figures compare favorably with estimates of total reserves made by Murphy and Vilbrandt, about 85 million tons of $(NH_4)_2SO_4$ and 35 million tons of $Ca_3(PO_4)_2$ for the entire Deep River field.

The nitrogen and phosphorus contents of the shale and blackband of the Deep River coal field are not exceptionally high, and only a small part of the total nitrogen and phosphorus present is in a form that can be assimilated by plants. Therefore, the value of these rocks as fertilizer may be partly a result of other minor constituents, for which tests have not been made.

BLACKBAND IRON ORES

Blackband beds associated with the Cumnock and Gulf coal beds are characterized by a relatively high content of siderite and limonite, which gives them a distinctive brownish-black color and a brown streak. The metallic iron content of these rocks, which averages about 15 percent, may be increased to nearly 40 percent by roasting and concentration. Although these blackband beds have been mined with the coal in the past, they have not been used to produce iron—except possibly to a limited extent in the old Endor iron furnace, 1 mile southeast of Cumnock, which was in operation after the Civil War. To determine whether a marketable ore could be produced from this rock, a 30-pound sample of blackband from the Carolina mine was subjected to beneficiation tests by the U. S. Bureau of Mines. The results of these tests were summarized by the Bureau of Mines Mineral Dressing Unit, College Park, Md., in the Eastern region report for March 1944, as follows:

> Sink-float tests were run using a medium of zinc chloride solution with specific gravity of 1.80. A poor separation was made because of the locked gangue minerals.
>
> Roasting to remove carbonaceous material increased the iron content from 16.4 percent to 28.3 percent, and magnetic concentration of the roasted ore at minus 100 mesh yielded a product that contained 38.1 percent iron, 18.9 percent insoluble, 3.1 percent phosphorus, and 2.2 percent sulphur.
>
> Extremely fine grinding would be required to liberate the iron bearing minerals and it is doubtful that the ore would be of value due to its high phosphorus and sulphur content.

Siderite nodules, as much as 12 inches in maximum diameter, are present locally in shales above the Cumnock coal bed in sufficient quantity to form a "ball ore" having about the same iron content as the blackband ores. Emmons and Kerr also noted the presence of "ferriferous limestones" near Cumnock, which contained as much as 33 percent iron. Analyses of the "ball" and blackband iron ores from pits near Gulf, published by Kerr (1875, p. 226–228), are summarized below:

Analyses of iron ores (in percent) from the Cumnock formation, near Gulf

1. Stratigraphic position not known, analysis by Buck. 2. From 3 feet above main coal bench, Cumnock coal bed, analysis by Hanna. 3. From 12-inch bed, 16 inches above main coal bench, Cumnock coal bed, analysis by Hanna. 4. From 18-inch bed, immediately below main coal bench, Cumnock coal bed, analysis by Hanna]

	Ball ore		Blackboard ore	
	1	2	3	4
SiO_2	6.04	5.188	7.089	9.154
Al_2O_3	.48	4.060	.127	4.244
FeO	14.51	9.614	33.802	19.419
Fe_2O_3	1.63	.938	1.755	-------
FeS	-------	7.146	2.145	10.485
CaO	29.57	14.040	12.672	9.520
MgO	6.51	.863	1.170	1.490
MnO	-------	1.500	1.980	1.750
SO_4	.19	.152	.170	trace
P_2O_5	.92	6.300	6.820	4.960
Volatile or organic matter	1.45	15.009	27.215	22.065
C	-------	34.473	4.726	16.213
H_2CO_3	38.30	-------	-------	-------
H_2O	.40	.717	.300	.700
Total	100.10	100.000	99.971	100.000
Roasted ore	-------	48.571	72.070	60.475
Computed from roasted ore:				
Metallic iron	-------	23.619	39.593	33.032
Sulfur	-------	.360	.800	.839
Phosphorus	-------	5.664	4.131	3.581

TABLE 17.—*Reserves of ammonium sulfate $(NH_4)_2SO_4$ and calcium phosphate $Ca_3(PO_4)_2$ in black shale and blackband of the Cumnock formation north of the Deep River fault*

Thickness of overburden (feet)	Beds	Thickness of individual beds (feet)	Average combined thickness of all beds (feet)	Acres	Acre-feet	Total reserves of shale and blackband (thousands of short tons, assuming 2,800 tons per acre-foot)	Recoverable reserves of shale and blackband (thousands of short tons, assuming 65% recovery)	Yield of $(NH_4)_2SO_4$ (pounds per ton)	Content of $(NH_4)_2SO_4$ in recoverable reserves of shale and blackband (thousands of short tons)	Yield of $Ca_3(PO_4)_2$ (pounds per ton)	Content of $Ca_3(PO_4)_2$ in recoverable reserves of shale and blackband (thousand of short tons)
0 to 200	Shale beds above Cumnock coal bed	<50	88	366	32, 208	90, 182	58, 618	50	1, 465	25	733
		>50	108	165	17, 820	49, 896	32, 432	35	568	10	162
	Blackband beds associated with Cumnock coal bed	<1	1	310	310	868	564	43	12	20	6
		1–3	3. 5	165	578	1, 618	1, 052	43	23	25	13
		<3	None								
	Blackband beds associated with Gulf coal bed	<1	. 5	56	28	78	51	46	1	25	1
		1–3	2	165	330	924	601	46	14	25	8
		>3	None								
	Total				51, 274	143, 566	93, 318		2, 083		923
200 to 2, 000	Shale beds above Cumnock coal bed	<50	83	9, 557	793, 231	2, 221, 047	1, 443, 681	50	36, 092	25	18, 046
		>50	92	8, 028	738, 576	2, 068, 013	1, 344, 208	35	23, 524	10	6, 721
	Blackband beds associated with Cumnock coal bed	<1	1	6, 983	6, 983	19, 552	12, 709	43	273	20	127
		1–3	3	7, 888		66, 259	43, 068	43	926	25	538
		>3	4	140		1, 568	1, 019	43	22	25	13
	Blackband beds associated with Gulf coal bed	<1	.75	1, 596	1, 197	3, 352	2, 179	46	50	20	22
		1–3	2. 5	4, 975	12, 438	34, 826	22, 637	46	521	20	226
		>3	None								
	Total				1, 576, 649	4, 414, 617	2, 869, 501		61, 408		25, 693
2, 000 to 3, 000	Shale beds above Cumnock coal bed	<50	50	2, 997	149, 850	419, 580	272, 727	45	6, 136	20	2, 727
		>50	55	2, 997	164, 835	461, 538	300, 000	30	4, 500	10	1, 500
	Blackband beds associated with Cumnock coal bed	<1	1	2, 873	2, 873	8, 044	5, 228	43	112	20	52
		1–3	2	2, 873	5, 746	16, 089	10, 458	43	225	20	104
		>3	15	123	1, 845	5, 166	3, 358	43	72	20	34
	Blackband beds associated with Gulf coal bed	<1	1	247	247	692	450	40	9	15	3
		1–3	None								
		>3	3. 5	123.	431	1, 207	784	40	16	15	6
	Total				325, 827	912, 316	593, 005		11, 070		4, 426
	Total recoverable reserves 0–3,000 feet of cover						3, 555, 824		74, 561		31, 042

TABLE 18.—*Content of shale oil, fertilizer ingredients, and metallic iron in recoverable reserves of blackband associated with the Cummock coal bed north of the Deep River fault*

	0–200 feet of cover	200–3,000 feet of cover
Recoverable reserve of blackband (as rock)	1,616,000 tons.	75,840,000 tons.
Shale oil (assuming 3.5 gal. per ton)	5,656,000 gallons.	265,440,000 gallons.
Ammonium sulphate $(NH_4)_2SO_4$	35,000 tons.	1,630,000 tons.
Calcium phosphate $Ca_3(PO_4)_2$	19,000 tons.	868,000 tons.
Metallic iron	242,000 tons.	11,376,000 tons.

MINING PROCEDURE

Beds of black shale above the Cumnock coal bed that have the highest yield of shale oil, nitrogen, phosphorus, and iron are separated from each other and from the coal bed by strata that yield very little of any of these products. These beds of shale must be mined separately. It is unlikely that the total value of all the constituents of these beds is great enough to permit mining and processing the rock.

Beds of blackband associated with the Cumnock and Gulf coal beds can be mined with the coal, and, in fact, often they must be removed to provide headroom in mining. Therefore these beds provide the most readily accessible reserve of shale oil, fertilizer filler, and iron in the Deep River field. Table 18 summarizes the reserves contained in beds of blackband associated with the Cumnock coal bed north of the Deep River fault.

Part of the shale and blackband along the outcrop of the Cumnock formation between Gulf and Haw Branch, which lies within 200 feet of the surface, may be recovered by stripping. The reserves in beds of this category are listed in tables 17 and 18.

URANIUM CONTENT OF SHALES

Tests made by the U. S. Geological Survey on 486 feet of core from the Cumnock formation in drill hole BMDH DR–1 (including all strata in this formation above the main bench of the Cumnock coal bed) show that the uranium content of these rocks ranges from 0.001 percent to 0.003 percent and is too small to be economically important.

CLAY PRODUCTS

BRICK AND TILE

The manufacture of brick has long been an important industry in the Deep River coal field. Favored by its central location in the state, by an excellent network of highways and railroads, and by abundant deposits of claystone, this area has produced a large part of the brick used in North Carolina. Within the past few years, three new plants using modern, tunnel-type kilns have been placed in operation. In 1950, plants in the Deep River coal field produced almost three-fourths of a million bricks per day. A list of the brick producers, locations of plants, and sources of raw materials is given below.

Brick and tile producers in the Deep River coal field in 1950

Producer	Location of plant	Source of raw materials
Borden Brick & Tile Co.	1 mile north of Sanford, Lee County.	Claystone from beds about 1,100 feet above base of Sanford formation.
Chatham Brick & Tile Co.	1 mile east of Gulf, Chatham County.	Claystone from beds about 500 feet above base of Sanford formation.
Cherokee Brick Co.	10 miles northeast of Sanford, Brickhaven, Chatham County.	Claystone from beds near top of Pekin formation.
Lee Brick & Tile Co.	5 miles north of Sanford, Lee County.	Siltstone and claystone from beds about 200 feet above base of Pekin formation.
Pomona Terra Cotta & Tile Co.	1 mile north of Gulf, Chatham County (plant located at Pomona, N. C.).	Claystone from beds near middle of Pekin formation.
Sanford Brick & Tile Co.	4 miles northeast of Sanford, Colon, Lee County.	Siltstone and claystone from beds near middle of Pekin formation.

Most of the brick produced in the Deep River coal field is now made from beds of massive red claystone in the Pekin and Sanford formations. Generally, these claystones can be extracted easily with a power shovel or scraper, they require little or no grinding, and they need only the addition of water to make them ready for molding and cutting. High-grade brick, face brick, and tile are produced from these beds. Patches of purple or green clay are present in some claystone beds in the Pekin formation and in the lower 600 feet of the Sanford; bricks made from claystone extensively mottled with such patches usually are not as strong as those made from uniformly red claystone. The thickest, most numerous, and most uniform beds of red claystone in the Deep River area are stratigraphically between 600 and 2,000 feet above the base of the Sanford formation, crop out in a belt starting in Lee County, west of Sanford, and extend southeastward into Moore County. Unfortunately, this area is several miles from railroad facilities.

Brick plants equipped with grinding and mixing facilities may utilize siltstone and fine-grained sandstone in mixtures containing at least half clay or claystone. Beds of siltstone and sandstone are usually avoided, however, because of the greater difficulty of extraction and preparation.

Formerly, the plant at Brickhaven used clays of Pleistocene and Recent age from terraces along the Cape Fear River. Clays from the terraces east of the Chatham Brick and Tile Co. plant, near Gulf, are known to yield excellent fire brick, and it is probable that many other terraces contain deposits of clays that are suitable for this purpose.

CEMENT MATERIALS

In response to a growing demand for the establishment of a cement industry in North Carolina, investigations have recently been made in regard to the possibility of using raw materials from the Deep River coal field in the manufacture of cement. Experiments conducted at North Carolina State College (Adair, R. B., and others, 1947) have shown that the proper blending of limestone or marl from eastern North Carolina with claystone from the Deep River coal field will produce material having the proper composition and physical properties for making portland cement. Specifically, these experiments demonstrated that some of the massive red or brown claystone beds in the Pekin and Sanford formations have satisfactory compositions for use in making cement; the best sample for this purpose, collected in a road cut on U. S. Highway 421, south of Cumnock, had the following percentage composition:

SiO_2, 60.62; Al_2O_3, 23.45; Fe_2O_3, 6.60; CaO, 1.15; MgO, 1.19; Na_2O, 1.13; and K_2O, 0.13.

A cement industry would require a large supply of claystone of approximately the above-mentioned composition. To locate such a deposit will necessitate careful sampling and analysis of the Triassic claystones, because there is a considerable range of compositions even among claystones of similar appearance. To establish the relationship between physical properties and chemical composition, samples of claystone and shale from the Deep River area have been collected and analyzed by the Department of Engineering Research of North Carolina State College and by the U. S. Geological Survey. These samples are described below, the analyses are listed in table 19, and the locations of the samples are shown on the lithologic map (pl. 4).

Locations and descriptions of claystone and shale samples

[Collector: 1, North Carolina State College; 2, U. S. Geol. Survey]

Sample No.	Collector	Location	Formation	Description
C–1	1	Road cut, 1 mile north of Carolina mine.	Pekin	Channel sample of moderate reddish-brown (10 R 4/6) claystone.
C–2	1	Road cut, 1 mile north of Carolina mine.	do	Composite of grab samples along 100 feet of outcrop (same bed sampled at C–1).
C–3	1	Clay pit of Lee Brick & Tile Co., 5 miles north of Sanford.	do	Grab sample of grayish-red (10 R 4/2) claystone.
C–4	1	Clay pit of Pomona Terra Cotta & Pipe Co., 1 mile west of Gulf.	do	Grab sample of moderate reddish-brown (10 R 4/6) claystone.
C–5	2	Road cut on State Highway 22, 6 miles northwest of Carthage.	do	Composite of 3 channel samples of 10-foot bed of dark reddish-brown (10 R 3/4) claystone along 50 feet of outcrop.
C–6	2	Road cut at junction of State Highways 22 and 27, 5 miles west of Carthage.	do	Channel sample of 5-foot bed of moderate reddish-brown (10 R 4/6) claystone in a series of alternating claystone and silty claystone in 1- to 5-foot beds.
C–7	1	Road cut on U. S. Highway 421, at Gulf.	Cumnock	Channel sample of 5-foot bed of black shale.
C–8	1	Road cut on U. S. Highway 421, south of Cumnock.	Sanford	Channel sample of 10-foot bed of moderate reddish-brown (10 R 4/6) claystone below a sandy layer.
C–9	1	do	do	Channel sample of 15-foot bed of moderate reddish-brown (10 R 4/6) claystone above a sandy layer.

Locations and descriptions of claystone and shale samples—Con.

Sample No.	Collector	Location	Formation	Description
C-10	1	Road cut on U. S. Highway 421, south of Cumnock.	Sanford	Channel sample of same bed sampled at C-9.
C-11	1	do	do	Composite of five channel samples of beds sampled at C-8 and C-9.
C-12	1	Clay pits of Chatham Brick & Tile Co., 1 mile east of Gulf.	do	Composite of several spot samples of red or brown claystones.
C-13	1	Clay pits of Borden Brick & Tile Co., 1 mile north of Sanford.	do	Composite of several spot samples of red or brown claystones.
C-14	2	Road cut on U. S. Highway 421, at Gulf.	do	Channel sample of middle 6 feet from 10-foot bed of dark reddish-brown (10 R 3/4) claystone.
C-15	2	Road cut on U. S. Highway 421, 3 miles northwest of Sanford.	do	Channel sample of 3-foot bed of moderate reddish-brown (10 R 4/6) claystone.
C-16	2	Road cut, 2 miles south of Sanford.	do	Composite of 4 channel samples of 6-foot bed of moderate reddish-brown claystone (10 R 4/6) along 25 feet of outcrop.
C-17	2	Road cut on Sanford-Carbonton Rd., 1 mile west of Sanford.	do	Channel sample of 8-foot bed of moderate reddish-brown (10 R 4/6) claystone, slightly silty.
C-18	2	Road cut on Sanford-Carbonton Rd., 5 miles west of Sanford.	do	Channel sample of 8-foot bed of moderate reddish-brown claystone, including silty layer 3 feet from top.
C-19	2	Road cut on Sanford-Carbonton Rd., 8 miles west of Sanford.	do	Channel sample of 5-foot section in upper part of 15-foot bed of moderate reddish-brown (10 R 4/6) claystone containing a few light-gray clay stringers.
C-20	2	Road cut, 1 mile southwest of Pocket Church.	do	Composite of 4 channel samples of 4-foot bed of dark reddish-brown (10 R 3/4) claystone, greasy to touch.
C-21	2	Road cut on Sanford-Carbonton Rd., 5 miles west of Sanford.	do	Channel sample of 8-foot bed of dark reddish-brown (10 R 3/4) claystone, slightly silty.
C-22	2	Road cut, 1 mile south of Pocket Church.	do	Composite of 5 spot samples of 3-foot bed of moderate reddish-brown (10 R 4/6) claystone along 100 feet of outcrop.
C-23	2	Road cut, 4 miles north of White Hill.	do	Channel sample of 6-foot bed of moderate reddish-brown (10 R 4/6) claystone with scattered yellow limonite patches, greasy to touch.
C-24	2	Road cut, 3 miles west of Pocket Church.	do	Channel sample of 3 separate 3-foot beds of moderate reddish-brown (10 R 4/6) claystone in a 20-foot section containing two 3-foot beds of fine-grained sandstone.

Claystone having preferred composition for use with limestone from eastern North Carolina in the making of cement is usually moderate reddish-brown (10 R 4/6), soft, structureless, in beds from several feet to several tens of feet thick, and weathers to pellets or granules of friable clay, which become coherent and plastic when moist. However, all claystone having such properties does not necessarily have the same composition. Although samples 1, 2, 4, 6, 8, 9, 10, 11, 15, 16, 22, and 24 (listed above) are similar in appearance, they have silica contents ranging from 58.00 percent to 72.21 percent and have alumina contents ranging from 12.91 percent to 24.54 percent. Moreover, the same claystone bed may have a considerable range of compositions. Samples 9 and 10 differ in composition by several percent, even though they are channel samples from the same bed at nearby points. Samples 1 and 2, which are lateral and vertical samples of the same bed in the same road cut, differ by almost 4 percent in silica content and differ about 2 percent in alumina content. These differences indicate that to locate large deposits of claystone having a uniform composition it will be necessary to systematically sample and analyze beds of claystone of the proper physical characteristics in those parts of the field where the claystone beds are thickest, most uniform, and most accessible. As stated above, the red or brown claystones are best developed in the Sanford formation in the area west of Sanford in Lee and Moore Counties, and the greatest reserve of claystone suitable for the manufacture of cement is probably to be found there.

SAND AND GRAVEL

Sand is the most abundant constituent of the post-Triassic deposits along the inner edge of the Coastal Plain. In the Sand Hills south and southwest of the Deep River coal field, these deposits contain large quantities of relatively clean, white or gray quartz sand, which has been used commercially in large quantities for many years. Within the area covered by the geologic map (pl. 1), however, most of the sand contains large amounts of gray or brown silt and yellow or orange clay, and it has been used only to a limited extent for local construction purposes. The thickest deposits of sand that contain relatively small amounts of silt or clay are southwest of Lemon Springs (in the south-central part of the mapped area), and southwest of Carthage (near the southwestern end of the mapped area).

Gravel is present in discontinuous patches in the post-Triassic deposits along the southeastern side of the Deep River field. The largest of these patches underlies the town of Carthage and extends for a distance of 4 miles east of Carthage. Remnants of this sinuous, channel-like deposit are also present southwest of Carthage. Locally, this deposit exceeds 15 feet in thickness. It consists of 25 to 70 percent white or light-gray, subrounded to well-rounded quartz pebbles and cobbles, as much as 8 inches across, in a matrix consisting mainly of fine- to coarse-grained, brown or orange sand (see fig. 27). Large quantities of this gravel have been removed from pits about 2 miles east of Carthage for use in road building and construction.

Irregular patches of sandy gravel, generally less than 10 feet thick, are present in the lower part of the post-Triassic deposits from White Hill to Tramway. They consist of white or gray, subangular to rounded quartz pebbles, cobbles, and boulders, together with angular

TABLE 19.—*Percentage analyses of claystone and shale samples from the Pekin, Cumnock, and Sanford formations*

Constituents	Pekin formation—red and brown claystone						Cumnock formation—black shale	Sanford formation—red and brown claystone																
	C-1 [1]	C-2 [2]	C-3 [1]	C-4 [1]	C-5 [3]	C-6 [3]	C-7 [2]	C-8 [2]	C-9 [2]	C-10 [1]	C-11 [1]	C-12 [1]	C-13 [1]	C-14 [3]	C-15 [3]	C-16 [3]	C-17 [3]	C-18 [3]	C-19 [3]	C-20 [3]	C-21 [3]	C-22 [3]	C-23 [3]	C-24 [3]
SiO_2	64.00	60.11	68.20	58.00	64.30	68.62	47.19	63.07	60.62	62.36	64.30	55.24	59.52	67.61	67.03	68.28	72.48	73.87	62.97	71.59	73.80	66.34	54.05	72.21
Al_2O_3	21.26	23.36	13.21	19.91	16.21	14.04	42.24	24.54	23.45	21.30	20.74	21.73	18.99	14.72	14.90	14.79	12.56	12.08	17.76	13.60	11.87	15.54	21.45	12.91
Fe_2O_3	5.72	6.05	9.55	8.39	5.65	5.39	5.28	6.93	6.60	5.72	6.30	8.39	8.17	5.22	4.96	5.59	4.44	4.09	6.29	4.46	3.94	4.68	6.24	4.08
FeO	----	----	----	----	.72	.50	----	----	----	----	----	----	----	.42	.58	.34	.32	.38	.27	.28	.48	.50	1.36	.46
CaO	.22	1.30	.20	.81	.23	.33	1.98	1.52	1.15	.10	.34	.25	.64	.52	.48	.10	.10	.09	.10	.09	.18	.22	.66	.20
MgO	1.44	.89	1.43	2.61	1.64	1.38	.43	.97	1.19	1.53	1.70	2.25	2.56	1.21	1.55	1.33	1.30	1.15	1.25	1.22	1.02	1.87	2.26	.66
Na_2O	----	1.55	----	----	1.28	1.26	.03	2.16	1.13	----	----	----	----	2.14	2.08	.06	.64	1.79	.08	.36	2.04	1.66	1.84	1.48
K_2O	----	.02	----	----	3.22	2.37	.04	.27	.13	----	----	----	----	1.86	2.60	2.42	1.89	1.95	3.02	2.36	2.04	2.92	4.43	2.30
TiO_2	----	----	----	----	.66	.77	----	----	----	----	----	----	----	.69	.64	.60	.64	.69	.65	.64	.61	.60	.69	.68
P_2O_5	----	----	----	----	.56	.45	----	----	----	----	----	----	----	.43	.50	.44	.40	.47	.55	.44	.39	.55	.58	.58
MnO	----	----	----	----	.08	.06	----	----	----	----	----	----	----	.07	.15	.05	.07	.04	.03	.06	.10	.07	.13	.05
Loss on ignition	5.47	----	5.48	6.14	5.02	4.50	----	----	----	7.09	4.82	8.61	6.46	4.64	4.12	6.52	4.74	3.41	6.75	4.71	3.13	4.61	6.35	3.95
Total	98.11	93.28	98.07	95.86	99.57	99.67	97.19	99.46	94.27	98.10	98.20	96.47	96.34	99.53	99.59	100.52	99.58	100.01	99.72	99.81	99.60	99.56	100.04	99.56

[1] Analyses from Beatty and Adair (1948, p. 23).
[2] Analyses from Adair and others (1947, p. 17).
[3] Analyses by Charlotte M. Warshaw and W. W. Brannock, U. S. Geol. Survey.

fragments of metamorphic rocks probably derived from the underlying pre-Triassic rocks, in a matrix of gray or brown sand or silt that usually comprises at least half of the deposit. Thin patches of sandy gravel in the post-Triassic deposits northeast of Sanford consist of well-rounded pebbles and cobbles of gray, brown, or purple quartzite that is embedded in a brown or orange matrix composed of subangular, clear quartz grains in limonitic clay. These deposits, as well as those west of Tramway, have been used for road construction. The locations of these gravels, and of the more important gravel pits, are shown on plate 1.

Residual accumulations of gravel overlie the Triassic conglomerate and fanglomerate beds shown on plate 1. Generally, these accumulations are too thin to be of value, but to the south, east, and north of Colon, where most of the Triassic beds are conglomeratic, the residual gravels are several feet thick in some places and have been used locally for road surfaces. This gravel consists dominately of white, gray, or pink, angular to subrounded quartz pebbles and cobbles (forming as much as 75 percent of the deposit) with scattered fragments of metamorphic rocks and a gray or brown silty or sandy matrix.

Residual accumulations of quartz and metamorphic and igneous rock fragments are also present over most of the terrain underlain by pre-Triassic rocks. These deposits are too thin to be important, except to the south of Hallison and to the east of Sanford, near the Sanford water works.

Terrace deposits along the Deep, Haw, and Cape Fear Rivers consist mainly of sand, silt, and clay, and contain only scattered pebbles and cobbles, but locally there are lenses or surface accumulations of gravel thick enough to be worked. Most of the high terraces contain residual surface gravels, whereas most of the lower terraces are covered with silt or clay as a result of recent flooding. High-terrace gravels south of Carbonton, north of Cumnock, and north of the Carolina Mine have been used for road construction.

STONE

Parts of the basal conglomerate of the Pekin formation are characterized by an abundance of white or gray quartz pebbles, a dark gray or brown standstone matrix, and quartz cement. This rock, which has been described in detail in the discussion of the Triassic sedimentary rocks, is known as the "millstone grit." It is a facies of the basal conglomerate that, locally, is in lenticular beds as much as 30 feet thick, interbedded with, and grading laterally into, conglomerate beds containing a higher proportion of metamorphic rock fragments and little, or no, quartz cement.

The "millstone grit" is irregularly distributed along the northwestern edge of the Sanford basin, and it is thickest and most extensive south of Putnam, where it has been quarried and used for millstones at many places. The largest of these quarries is on a branch of Richland Creek, a few hundred feet west of State Highway 22. This quarry was operated intermittently for almost 100 years, beginning in the early part of the last century, but it is now flooded and overgrown with dense vegetation. "Millstone grit" also crops out locally north and east of the Carolina Mine and north and west of Gulf, but it has not been quarried there. An old quarry in the forest east of Horse Shoe Bridge contains a lens of conglomerate in the Sanford formation, which resembles the "millstone grit."

Triassic sandstone has been quarried at several places for building stone. Quarries near Sanford produced fine- and medium-grained, dark reddish-brown (10 R

3/4) sandstone, which was used in the construction of the Lee County courthouse and other buildings. This is the same type of stone, commonly known as "brownstone," which has been quarried in most of the eastern Triassic areas, and which formerly was widely used as a facing stone in the construction of buildings in many eastern cities. Although this is a durable building stone and although there is a large supply available, it has been supplanted by cheaper and more popular construction materials. Arkosic sandstone from the Sanford formation has been quarried near Gulf, but this rock is not durable enough for use as a building stone.

Triassic diabase is a very tough, durable rock that has been used extensively for surfacing roads in many eastern states. This rock, which is about as hard as granite, might also be used as a facing stone in construction. It has not been used to any appreciable extent in the Deep River coal field.

Pre-Triassic (Carboniferous?) granite has been quarried for building stone. The largest granite quarry near the Deep River coal field is along the Seaboard Railroad, 2 miles north of Lemon Springs. Pre-Triassic slate southeast of Goldston has been used extensively for surfacing roads.

PYROPHYLLITE

Commercially important deposits of pyrophyllite in lenticular bodies, as much as a third of a mile long and several hundred feet wide, are present in the pre-Triassic rocks west of the Deep River coal field. These deposits are in a belt of pyrophyllite-bearing schist that begins near Indian Creek, about 2 miles north of Carbonton, and extends S 60° W for a distance of about 10 miles. Several mines and prospects have been opened along this belt (see pl. 1). One of the largest of these mines (and the only one operating in 1950) is the Phillips mine, 2 miles north of Glendon. Mining is by open cut and subsurface methods, and the ore is hauled to Glendon, where it is ground and shipped.

The pyrophyllite deposits have been described by Stuckey (1928, p. 46–52). They usually are in acid volcanic tuff of rhyolitic or dacitic composition, and in the mines near Glendon they overlie a hematite-rich volcanic breccia. Stuckey believes that they have been formed by metasomatic replacement of the acid rocks along lines of shearing that accompanied the folding of these rocks. For a detailed description of these deposits and associated rocks, the reader is referred to Stuckey's report.

GOLD

Although gold has been mined in considerable quantity at some places in the pre-Triassic slate belt of central North Carolina, no commercial deposits have been found in the vicinity of the Deep River coal field. Small amounts of gold are associated with the pyrophyllite deposits along the northwestern side of the field. Traces of gold were found in the granite area near the Sanford water works, and considerable prospecting was done in that area about 1900, but without success.

IRON

In addition to the sideritic and limonitic blackband iron ores (already described), the Triassic rocks contain local concentrations of hematite and limonite, which have been mined in the past. Kerr (1875, p. 225) states that hematite ore in a bed 20 to 25 inches thick, containing 65 to 70 percent ferric oxide, was mined at Haywood, and he states that a similar bed was mined about a mile north of Sanford. These ores were accumulations of hematite pellets usually less than an inch wide. Campbell and Kimball noted masses of hematite several feet wide in the Pekin formation near Colon.

Hematite or red limonite are disseminated through the Pekin and Sanford formations, and although they usually form less than 5 percent of the rock, the red color of most of these rocks is caused by these minerals. Concentrations of these ferric oxides are produced by ground water that has dissolved these minerals and redeposited them in two forms: (1) as an iron-rich cement filling the interstices near the bottoms of sandstone and conglomerate beds (where such beds overlie less permeable strata), and (2) as iron-rich concretionary grains or pellets in red or brown claystone, siltstone, and sandstone (especially, near fault zones). Hematite pellets are commonly associated with irregular gray or green patches of rock resulting from partial reduction, or removal, of the ferric oxide originally disseminated through the rock. No concentrations of hematite or limonite large enough to be commercially important have been observed in the Deep River Triassic basin, and it is unlikely that any such deposits exist.

Deposits of hematite and limonite are present also in the pre-Triassic rocks near the Deep River coal field. A bed of specular hematite, 3 to 6 feet thick, is located about 3 miles south of Buckhorn Dam on the east bank of the Cape Fear River; this bed, and a smaller ore body located about 2 miles below the dam, were mined after the Civil War by the American Iron and Steel Company. The ore was carried, by boat, upstream to the old Endor iron furnace on Deep River, 1 mile southeast of Cumnock, where it was used in the manufacture of car wheels. A smaller deposit of hematite is located 6 miles north of Gulf. The largest iron deposit in the region is at Ore Hill, 6 miles north of Goldston, where limonite occupies several short veins that have diverse strikes and dips and are locally more than 10 feet wide. Some of this ore was mined during the Revolutionary War (when it was used in the Wilcox forge at Gulf), during the Civil War, and intermittently during the last part of the 19th century.

COPPER

Traces of copper appear at several places in the pre-Triassic rocks northwest of the Deep River basin, but the only locality near the Deep River coal field that has yielded copper in commercial quantity is in northern Lee County, near the Deep River consolidated school (see pl. 1). A prospect pit, a flooded shaft, and a tailings dump are the only remaining evidences of the former mine operations. The shaft goes down along a northeast-trending quartz vein that can be followed on the surface for a distance of several hundred feet (one of many quartz veins in the vicinity). Specimens containing chalcopyrite (CuFeS), azurite ($2CuCo_3\,Cu(OH)_2$), malachite ($CuCo_3\,Cu(OH)_2$), and quartz were found near the shaft. This mine is probably the Clegg mine, discussed by Kerr (1875, p. 272), who states that the vein was followed to a depth of 200 feet. His description of this vein follows:

> The vein is quartz, with copper pyrites in talco-argillaceous and talco-quartzitic slates. Much of the veinstone, in depth, is a *talco-siliceous* and argillaceous breccia, of a gray and bluish mottled appearance together with a dark blue jaspery quartzitic rock. The vein is traceable for hundreds of yards through the forests by large outcrops of white quartz. The thickness of it in the workings was reported as ranging from three or four to six feet. Calcspar, in hexagonal prisms, occurs in the vein, and also in curved plates, enclosing masses of bituminous coal. The mine has also furnished fine specimens of azurite.

A report by the Sanford Herald on January 16, 1932, stated that this mine was last operated around 1900 and that it remained in operation for about 18 months at that time. About 180 men were employed; the ore was loaded on railroad cars at Osgood for shipment to processing plants.

Chalcopyrite, azurite, and malachite are associated with pyrite, hematite, and barite near faults or dikes in the Triassic of Virginia, but no copper mineralization has been reported in the Deep River Triassic basin.

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APPENDIX

DESCRIPTIVE LOGS OF DIAMOND-DRILL HOLES IN THE DEEP RIVER COAL FIELD

During the years from 1915 to 1950, 30 diamond-drill holes were put down to test the coal in the Deep River coal field. The locations of these holes are shown on plate 1. Listed below are the designations of these holes as used in this report, the organizations for which they were drilled, and the approximate dates of the drilling.

Drill hole No.	Organization	Dates
DH-1, 2, 3, 4	Norfolk-Southern Rd	1915–19
DH A-1, 2, 3, 4, 5	Eavenson, Alford & Hicks	1930
SDH (2 holes)	State of North Carolina	1935?
CPDH	Coal Products, Inc	1944
BMDH D-1, D-2, E-1, E-2, 1, 2	U. S. Bureau of Mines	1944–45
BDH 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	Walter Bledsoe & Co	1945–46
BMDH DR-1, DR-2	U. S. Bureau of Mines	1947–48

Records of holes DH–2, 3, and 4, and of the two SDH holes are not available. Records of the other 26 holes were used in preparing this report, and they are given in the following pages for the use of those interested in detailed information on the lithology of the Triassic rocks. The log of hole DH–1 has been published previously by Vilbrandt (1927, p. 18). The logs of the other 24 holes given below have not been published prior to this report, and their publication at this time is possible only through the generous cooperation of the organizations for which they were drilled.

The form of these logs has been changed to some extent in preparing them for publication, but their content has not been altered. Inasmuch as several individuals are responsible for preparing them, the descriptive terms used in the different logs are not entirely comparable. Thus, a rock listed as a red shale in one log might be the same rock that is listed as a reddish-brown claystone in another log prepared by a different individual. This is unfortunate, but it is impossible to harmonize these terms without re-examining the cores, most of which are no longer available. Footnotes to the logs call attention to the probable differences between the usage of terms in the logs and the usage of terms in this report. Descriptive terms in logs of holes BMDH DR–1 and DR–2 have the same meanings as the terms used in this report.

DIAMOND-DRILL RECORDS

Drill hole DH–1.
Location: approximately 1,800 feet S. 52° W. of main shaft of Cumnock mine, Lee County.
Surface altitude: 242 feet (approximate).
Date: 1915–19 (?).
Drilled for: Norfolk-Southern Railroad.
Logged by: Unknown.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
River terrace deposits (Quaternary):						
Sand	0		7		7	
Clay	7		14		7	
Sand	14		30		16	
Sanford formation (Triassic):						
Shale, red	30		32		2	
Shale, gray	32		40		8	
Shale, red	40		60		20	
Cumnock formation (Triassic):						
Shale, gray	60		86		26	
Slate, black	86		91		5	
Slate, gray	91		96		4	
Sandstone, dark-gray, hard	96		173		77	
Shale, gray	173		178		5	
Slate, black	178		186		8	
Slate, gray	186		238		52	
Slate, black	238		244		6	
Slate, gray	244		268		24	
Shale, black	268		275		7	
Sample O–1 (see table 15).						
Sample N–1 (see table 16).						
Shale, gray	275		297		22	
Slate, black	297		330		33	
Sample N–2 (see table 16).						
Slate, gray	330		355		26	
Shale, black, oil-bearing	355		387		32	
Sample O–2 (see table 15).						
Sample N–3 (see table 16).						
Slate, black	387		564		177	
Sample N–4 (see table 16).						
Sandstone, gray, hard	564		564	4		4
Slate and shale, black, oil-bearing	564	4	602	4	38	
Sample O–3 (see table 15).						
Sample N–5 (see table 16).						
Sandstone, gray	602	4	604	3	1	11
Slate, black	604	3	604	5		2
Sample N–6 (see table 16).						
Coal, high grade (Main bench, Cumnock Coal Bed)	604	5	608	3	3	10
Blackband, oil-bearing	608	3	609	9	1	6
Sample O–4 (see table 15).						
Sample N–7 (see table 16).						
Coal, low grade (Lower bench, Cumnock Coal Bed)	609	9	611	7	1	10
Blackband, oil-bearing	611	7	612	6		11
Sample O–4 (see table 15).						
Sample N–8 (see table 16).						
Slate, black	612	6	613	6	1	
Sample N–9 (see table 16).						
Fire clay	613	6	615		1	6
Slate	615		627		12	
Fire clay	627		642		15	
Blackband, oil-bearing	642		645		3	
Sample O–5 (see table 15).						
Sample N–10 (see table 16).						
Coal, fair (Gulf Coal Bed)	645		647	10	2	10
Blackband, oil-bearing	647	10	649		1	2
Sample O–5 (see table 15).						
Sample N–11 (see table 16).						
Sandstone	649		650		1	
Bottom of hole	650					

[1] In this record the term "slate" probably refers in part to fissile or very thin-bedded shale; "shale, gray" probably refers in part to gray claystone; and "shale, red" probably refers in part to red or brown claystone.

DIAMOND-DRILL RECORDS—Continued

Drill hole DH A–1.
Location: Approximately 3,500 feet S. 80° E. of main shaft of Cumnock mine, Lee County.
Surface altitude: 229.
Date: April 27, 1930.
Drilled for: Eavenson, Alford & Hicks.
Logged by: Thomas Korsmo.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
River terrace deposits (Quaternary):						
Not cored	0	------	26	------	26	------
Cumnock formation (Triassic):						
Slate, gray, soft	26	------	28	10	2	10
Brown clod	28	10	29	7	------	9
Slate, gray, soft	29	7	30	7	1	------
Slate, black	30	7	31	11	1	4
Slate, gray, soft	31	11	34	1	2	2
Shale, gray, hard	34	1	37	4	3	3
Sandstone, gray, fine-grained, hard	37	4	38	1	------	9
Shale, gray, dark	38	1	41	10	3	9
Shale, black	41	10	43	7	1	9
Shale, gray, hard, sandy	43	7	49	10	6	3
Sandstone, dark, green cast, hard	49	10	70	7	20	9
Slate, black, hard	70	7	72	2	1	7
Sandstone, dark, green cast, hard	72	2	76	------	3	10
Slate, black	76	------	76	11	------	11
Shale, dark-gray, white streaks	76	11	94	3	17	4
Slate, black	94	3	100	8	6	5
Shale, dark-gray	100	8	106	11	6	3
Shale, light-gray	106	11	121	4	14	5
Slate, black	121	4	125	6	4	2
Shale, light-gray	125	6	132	4	6	10
Slate, black	132	4	137	8	5	4
Shale, light-gray	137	8	142	1	4	5
Slate, black	142	1	148	3	6	2
Shale, light-gray	148	3	156	3	8	------
Shale, dark	156	3	159	9	3	6
Slate, black	159	9	163	8	3	11
Shale, dark	163	8	167	5	3	9
Shale, dark-gray	167	5	201	2	33	9
Shale, light-gray	201	2	221	------	19	10
Slate, dark	221	------	221	9	------	9
Slate, black	221	9	223	5	1	8
Slate, dark	223	5	225	8	2	3
Slate, light-gray	225	8	236	11	11	3
Slate, dark	236	11	237	6	------	7
Shale, light-gray	237	6	238	4	------	10
Slate, black	238	4	240	5	2	1
Slate, dark	240	5	243	------	2	7
Shale, light-gray	243	------	252	4	9	4
Slate, black	252	4	252	8	------	4
Shale, dark	252	8	256	6	3	10
Slate, black	256	6	257	------	------	6
Shale, dark	257	------	257	5	------	5
Slate, black	257	5	259	8	2	3
Slate, dark	259	8	261	8	2	------
Shale, light-gray	261	8	268	2	6	6
Slate, dark	268	2	271	5	3	3
Shale, light-gray	271	5	273	9	2	4
Slate, dark	273	9	278	7	4	10
Shale, light-gray	278	7	293	1	14	6
Slate, very dark	293	1	297	9	4	8
Shale, light-gray	297	9	301	9	4	------
Slate and shale	301	9	309	3	7	6
Slate, black	309	3	313	3	4	------
Slate, dark	313	3	314	3	1	------
Shale, dark	314	3	319	1	4	10
Slate, dark, and shale	319	1	331	11	12	10
Shale, light-gray	331	11	337	1	5	2
Slate, dark	337	1	337	7	------	6
Shale, dark	337	7	341	7	4	------
Slate, light-gray	341	7	344	7	3	------
Slate, dark	344	7	350	4	5	9
Shale, dark	350	4	353	6	3	2
Slate, dark	353	6	354	3	------	9
Shale, dark	354	3	358	10	4	7
Slate, dark	358	10	377	2	18	4
Slate, black	377	2	380	2	3	------
Shale, dark, fine-grained, very hard	380	2	387	8	7	6
Slate, black	387	8	391	4	3	8
Shale, argillaceous, with iron balls	391	4	405	------	13	8
Slate, very dark, with fossils	405	------	450	------	45	------
Shale, dark, with hard nodules	450	------	464	5	14	5
Slate, black, with fossils	464	5	493	6	29	1
Coal, hard, impure (Top bench, Cumnock Coal Bed)	493	6	494	3	------	9
Shale, dark	494	3	496	8	2	5
Draw slate	496	8	497	------	------	4
Coal (Main bench, Cumnock Coal Bed)	497	------	500	9	3	9
Blackband	500	9	502	5½	1	8½
Coal	502	5½	502	6	------	½

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole DH A–1—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Blackband	502	6	502	7	------	1
Coal	502	7	502	8	------	1
Blackband	502	8	502	10½	------	2½
Coal (Lower bench, Cumnock Coal Bed)	502	10½	504	½	1	2
Blackband, with coal laminations	504	½	505	9	1	8½
Fire clay	505	9	506	2	------	5
Slate, dark	506	2	807	1	------	11
Shale, light, with sandy laminations	507	1	511	------	3	11
Bottom of hole	511	------	------	------	------	------

[1] In this record the term "slate" probably refers in part to fissile shale and the term "shale, hard" probably refers in part to claystone or siltstone.

Drill hole DH A–2.
Location: Approximately 7,800 feet S. 52° E. of main shaft of Cumnock mine, south side of Deep River, Lee County.
Surface altitude: 234.
Date: May 17, 1930.
Drilled for: Eavenson, Alford & Hicks.
Logged by: John Hazlett.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Surface soil:						
No core	0	------	16	------	16	------
Sanford formation (Triassic):						
Shale, red	16	------	40	------	24	------
Sandstone, red	40	------	72	------	32	------
Shale, red, sandy	72	------	430	------	358	------
Shale, red and gray, sandy, hard	430	------	435	6	5	6
Shale, red, laminated with green	435	6	472	6	37	------
Sandstone, dark-gray, hard	472	6	478	------	5	6
Shale, red, laminated with green	478	------	532	6	54	6
Shale, green and red, sandy	532	6	539	6	7	------
Shale, red	539	6	545	6	6	------
Sandstone, green, laminated with red shale	545	6	550	10	5	4
Sandstone, gray	550	10	558	------	7	2
Sandstone, green	558	------	559	6	1	6
Sandstone, gray	559	6	561	8	2	2
Shale, red and green laminated	561	8	568	------	6	4
Shale, gray, hard, sandy	568	------	574	2	6	2
Shale, red, laminated with green	574	2	591	6	17	4
Shale, red	591	6	605	------	13	6
Shale, red, laminated with green shale	605	------	650	------	45	------
Shale, green, laminated with red, sandy	650	------	660	6	10	6
Shale, red	660	6	667	6	7	------
Shale, red and green laminated	667	6	675	------	7	6
Shale, red	675	------	695	6	20	6
Shale, gray, sandy	695	6	700	------	4	6
Shale, red, laminated with green	700	------	702	6	2	6
Shale, dark-gray, hard, sandy	702	6	713	------	10	6
Shale, dark with green cast, hard	713	------	717	------	4	------
Shale, dark with red cast	717	------	719	2	2	2
Shale, dark-gray with green cast, hard	719	2	724	2	5	------
Shale, dark with laminations of red and green cast	724	2	731	------	6	10
Cumnock formation (Triassic):						
Shale, dark-gray	731	------	751	------	20	------
Shale, dark with green cast, hard, sandy	751	------	778	6	27	6
Sandstone, gray, hard	778	6	781	6	3	------
Sandstone, black	781	6	786	------	4	6
Sandstone, dark-gray	786	------	795	------	9	------
Shale, black	795	------	797	2	2	2
Sandstone, dark, hard	797	2	809	2	12	------
Shale, black, hard	809	2	812	------	2	10
Shale, dark, laminated with gray, hard, sandy	812	------	818	6	6	6
Shale, black with streaks of gray sandstone	818	6	824	------	5	6
Shale, gray with green case, hard, sandy	824	------	839	6	15	6
Shale, dark	839	6	847	------	7	6
Shale, gray with green cast, hard	847	------	864	6	17	6
Shale, black	864	6	868	------	3	6

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole DH A-2—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Shale, gray with green cast, hard	868	------	874	------	6	------
Shale, black	874	------	880	------	6	------
Shale, gray with green cast, hard	880	------	885	------	5	------
Shale, black	885	------	890	------	5	------
Shale, gray with green cast, hard	890	------	898	------	8	------
Shale, black	898	------	904	6	6	6
Shale, dark and gray laminated with green cast, hard	904	6	956	6	52	------
Shale, black	956	6	960	------	3	6
Shale, dark and gray laminated with green cast, hard	960	------	1,002	------	42	------
Shale, dark	1,002	------	1,006	6	4	6
Shale, dark-gray with green cast	1,006	6	1,012	6	6	------
Shale, dark with green cast, hard	1,012	6	1,019	------	6	6
Shale, black	1,019	------	1,022	6	3	6
Shale, dark with streaks of sandstone	1,022	6	1,032	------	9	6
Slate, black	1,032	------	1,036	6	4	6
Shale, dark with dark sandy shale streaks	1,036	6	1,100	------	63	6
Shale, black	1,100	------	1,104	------	4	------
Shale, dark	1,004	------	1,106	------	2	------
Slate, black, with fossils	1,006	------	1,110	3	4	3
Slate, dark	1,110	3	1,113	7	3	4
Shale, dark	1,113	7	1,118	1	4	6
Shale, dark, with sandy streaks and fossils	1,118	1	1,127	1	9	------
Slate, dark, with fossils	1,127	1	1,136	1	9	------
Slate, black, with fossils	1,136	1	1,145	7	9	6
Shale, light, sandy	1,145	7	1,147	7	2	------
Slate, very dark, with fossils	1,147	7	1,152	1	4	6
Shale, dark, sandy	1,152	1	1,154	1	2	------
Slate, black, with fossils	1,154	1	1,157	8	3	7
Shale, dark, sandy	1,157	8	1,158	4	------	8
Sandstone	1,158	4	1,158	7	------	3
Shale, gray, laminated with dark slate, sandy, with fossils	1,158	7	1,160	2	1	7
Slate, black	1,160	2	1,160	8	------	6
Shale, gray laminated with slate, sandy	1,160	8	1,161	6	------	10
Slate, very dark, with fossils	1,161	6	1,167	8	6	2
Shale, gray, sandy	1,167	8	1,170	8	3	------
Shale, dark, with fossils	1,170	8	1,171	9	1	1
Slate, black	1,171	9	1,173	1	1	4
Sandstone, light-gray	1,173	1	1,173	10	------	9
Shale, dark laminated with slate, sandy, with fossils	1,173	10	1,181	2	7	4
Slate, very dark	1,181	2	1,182	7	1	5
Shale, dark	1,182	7	1,183	5	------	10
Slate, black	1,183	5	1,183	8	------	3
Shale, very hard, sandy	1,183	8	1,184	3	------	7
Slate, black laminated with sandy shale	1,184	3	1,185	2	------	11
Shale, dark, very hard	1,185	2	1,185	10	------	8
Slate, black, with fossils	1,185	10	1,202	11	17	1
Sandstone, dark	1,202	11	1,203	2	------	3
Slate, black, with fossils	1,203	2	1,206	7	3	5
Sandstone, dark	1,206	7	1,207	8	1	1
Slate, black, with fossils	1,207	8	1,210	8	3	------
Slate, black with coal laminations	1,210	8	1,210	11	------	3
Slate, black, with fossils	1,210	11	1,212	8	1	9
Shale, gray, sandy, with fossils	1,212	8	1,213	9	1	1
Coal	1,213	9	1,214	3	------	6
Shale, dark, hard, sandy	1,214	3	1,219	11	5	8
Slate, black	1,219	11	1,220	3	------	4
Shale, dark, hard, sandy	1,220	3	1,222	------	1	9
Shale, black, hard	1,222	------	1,223	1	1	1
Coal, inferior	1,223	1	1,223	5	------	4
Shale, dark, hard	1,223	5	1,224	4¾	------	11¾
Coal, including 3 in. bottom bone coal (top bench, Cumnock coal bed)	1,224	4¾	1,226	2¾	1	10
Shale, light streaked	1,226	2¾	1,235	5¾	9	3
Shale, dark	1,235	5¾	1,235	9¼	------	3½
Coal and slate (Main bench, Cumnock Coal Bed)	1,235	9¼	1,238	3½	2	6¼
Shale, medium-dark	1,238	3½	1,240	1½	1	10
Coal and slate (lower bench, Cumnock Coal Bed)	1,240	1½	1,241	10½	1	9
Shale, gray, hard, sandy	1,241	10½	1,245	1½	3	3
Shale, light-gray, hard, sandy	1,245	1½	1,249	8½	4	7
Shale, light-gray	1,249	8½	1,253	1½	3	5
Soapstone	1,253	1½	1,254	6	1	4½
Bottom of hole	1,254	6	------	------	------	------

[1] In this record the term "slate" probably refers in part to fissile shale, "shale, hard" probably refers in part to claystone, "shale, sandy" probably refers in part to siltstone, and "shale, red" probably refers in part to red or brown claystone.

DIAMOND-DRILL RECORDS—Continued

Drill hole DH A–3.
Location: Approximately 6,500 feet S. 28° E. of main shaft of Cumnock mine, Lee County.
Surface altitude: 211.
Date: June 10, 1930.
Drilled for: Eavenson, Alford & Hicks.
Logged by: Thomas Korsmo.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Alluvium (Quaternary):						
Not cored	0	------	16	------	16	------
Sanford formation (Triassic):						
Shale, red	16	------	34	------	18	------
Shale, red, sandy	34	------	43	6	9	6
Shale, red	43	6	87	6	44	------
Sandstone, brown	87	6	108	6	21	------
Shale, red	108	6	161	------	52	6
Shale, red, with sandy streaks	161	------	175	6	14	6
Shale, red	175	6	207	------	31	6
Shale, red, sandy	207	------	213	6	6	6
Shale, red	213	6	264	6	51	------
Shale, red, sandy	264	6	275	6	11	------
Shale, red	275	6	347	6	72	------
Sandstone, brown	347	6	350	6	3	------
Shale, red with sandy laminations	350	6	358	------	7	6
Shale, red	358	------	438	6	80	6
Sandstone, brown coarse-grained	438	6	442	6	4	------
Shale, red	442	6	511	------	68	6
Sandstone, brown	511	------	513	------	2	------
Shale, red	513	------	534	------	21	------
Sandstone, brown	534	------	536	6	2	6
Shale, red	536	6	551	6	15	------
Sandstone, brown	551	6	555	6	4	------
Shale, red	555	6	570	------	14	6
Sandstone, brown	570	------	578	------	8	------
Shale, red	578	------	625	------	47	------
Sandstone, brown	625	------	630	------	5	------
Shale, red	630	------	719	6	89	6
Sandstone, brown	719	6	721	------	1	6
Shale, red	721	------	769	6	48	6
Sandstone, brown	769	6	776	------	6	6
Shale, red	776	------	862	6	86	6
Shale, red and green	862	6	866	------	3	6
Shale, red	866	------	951	6	85	6
Shale, red and green	951	6	955	------	3	6
Shale, red	955	------	959	------	4	------
Sandstone, brown	959	------	967	------	8	------
Shale, red	967	------	992	------	25	------
Sandstone, white	992	------	1,009	------	17	------
Shale, red	1,009	------	1,013	6	4	6
Sandstone, brown	1,013	6	1,017	6	4	------
Sandstone, white	1,017	6	1,020	6	3	------
Shale, red	1,020	6	1,043	------	22	6
Shale, red and green	1,043	------	1,047	6	4	6
Shale, red	1,047	6	1,067	------	19	6
Sandstone, white	1,067	------	1,072	6	5	6
Shale, red	1,072	6	1,082	6	10	------
Shale, red and green	1,082	6	1,121	6	39	------
Sandstone	1,121	6	1,131	6	10	------
Shale, red	1,131	6	1,149	6	18	------
Shale, red and green	1,149	6	1,155	------	5	6
Shale, green	1,155	------	1,181	6	26	6
Cumnock formation (Triassic)						
Shale, dark	1,181	6	1,188	3	6	9
Sandstone	1,188	3	1,195	3	7	------
Shale, green	1,195	3	1,201	6	6	3
Shale, gray	1,201	6	1,206	3	4	9
Shale, gray, sandy	1,206	3	1,209	6	3	3
Shale, green	1,209	6	1,222	6	13	------
Sandstone, green cast	1,222	6	1,228	6	6	------
Shale, green	1,228	6	1,237	6	9	------
Sandstone	1,237	6	1,238	4	------	10
Shale, dark	1,238	4	1,240	6	2	2
Sandstone, green cast, hard	1,240	6	1,244	6	4	------
Shale, dark	1,244	6	1,247	6	3	------
Sandstone, green cast, hard	1,247	6	1,259	6	12	------
Shale, dark	1,259	6	1,266	6	7	------
Shale, dark	1,266	6	1,274	6	8	------
Sandstone, with shale streaks	1,274	6	1,278	------	3	6
Slate, black	1,278	------	1,282	9	4	9
Shale, green cast	1,282	9	1,298	9	16	------
Shale, dark	1,298	9	1,304	9	6	------
Shale, green cast	1,304	9	1,317	7	12	10
Slate, black	1,317	7	1,320	1	2	6
Shale, green cast	1,320	1	1,324	7	4	6
Slate, black	1,324	7	1,331	1	6	6
Shale, green cast	1,331	1	1,336	11	5	10
Slate, black	1,336	11	1,341	11	5	------
Shale, dark	1,341	11	1,345	------	3	1
Shale, green cast	1,345	------	1,354	------	9	------
Shale, dark	1,354	------	1,360	9	6	9
Shale, green cast	1,360	9	1,372	9	12	------

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole DH A-3—Continued

Description [1]	Depth from surface: From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
Cumnock formation (Triassic)—Con.						
Shale, dark	1,372	9	1,378	4	5	7
Shale, green cast	1,378	4	1,408	10	30	6
Shale, dark	1,408	10	1,412	4	3	6
Shale, green cast	1,412	4	1,425	4	13	
Shale, dark	1,425	4	1,428	4	3	
Shale, green cast	1,428	4	1,438	10	10	6
Shale, dark	1,438	10	1,445	4	6	6
Shale, green cast	1,445	4	1,451	10	6	6
Shale, black	1,451	10	1,455	10	4	
Shale, green cast	1,455	10	1,478		22	2
Shale, dark	1,478		1,539	6	61	6
Shale, black	1,539	6	1,555	6	16	
Shale, dark	1,555	6	1,578		22	6
Slate, black, with hard shale laminations	1,578		1,608	2	30	2
Shale, black	1,608	2	1,612	8	4	6
Shale, gray, hard, calcareous	1,612	8	1,619	6	6	10
Slate, black, with hard shale laminations	1,619	6	1,629	6	10	
Shale, gray, hard, calcareous	1,629	6	1,644	3	14	9
Shale, dark	1,644	3	1,652	3	8	
Slate, black	1,652	3	1,664	6	12	3
Shale, dark	1,664	6	1,674	6	10	
Shale, gray, with sandstone streaks	1,674	6	1,684	8½	10	2½
Coal (Main bench, Cumnock Coal Bed)	1,684	8½	1,688	5½	3	9
Shale, dark, sandy	1,688	5½	1,688	11½		6
Sandstone	1,688	11½	1,689	6		6½
Shale, light- and dark-gray laminated	1,689	6	1,693		3	6
Shale, dark	1,693		1,693	10		10
Coal (Lower bench, Cumnock Coal Bed)	1,693	10	1,696	4	2	6
Shale, dark	1,696	4	1,700		3	8
Bottom of hole	1,700					

[1] In this record the term "slate" probably refers in part to fissile shale, "shale, hard" probably refers in part to claystone, "shale, sandy" probably refers in part to siltstone, and "shale, red" probably refers in part to red or brown claystone.

Drill hole DH A-4.
Location: Approximately 3,800 feet S. 44° E. of main shaft of Cumnock mine, Lee County.
Surface altitude: 232.
Date: April 13, 1930.
Drilled for: Eavenson, Alford & Hicks.
Logged by: John Hazlett.

Description [1]	Depth from surface: From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
River terrace deposits (Quaternary):						
Not cored	0		11	6	11	6
Sanford formation (Triassic):						
Shale, red	11	6	153	6	142	
Shale, gray and red laminated	153	6	155	6	2	
Shale, red	155	6	180		24	6
Shale, red, sandy	180		193	6	13	6
Shale, red and gray laminated	193	6	195	6	2	
Shale, red	195	6	233	6	38	
Shale, red, laminated with green	233	6	240		6	6
Shale, red, laminated with gray, sandy	240		245	6	5	6
Shale, red, sandy	245	6	277	6	32	
Shale, red, laminated with gray and green	277	6	302		24	6
Shale, red	302		315		13	
Shale, red, laminated with gray and green	315		316	6	1	6
Shale, red	316	6	321		4	6
Shale, gray	321		328	6	7	6
Shale, red	328	6	330		1	6
Shale, red and green laminated	330		331	6	1	6
Shale, red	331	6	348	6	17	
Shale, gray, laminated with red	348	6	355	6	7	
Shale, red	355	6	359	6	4	
Shale, red and green laminated	359	6	362	6	3	
Shale, red	362	6	373		10	6
Shale, red, laminated with gray	373		379		6	
Shale, red	379		387		8	

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole DH A-4—Continued

Description [1]	Depth from surface: From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
Sanford formation (Triassic)—Con.						
Shale, gray	387		390		3	
Shale, red, laminated with gray	390		391	6	1	6
Shale, red	391	6	395		3	6
Shale, red and gray laminated	395		399		4	
Shale, red	399		402	6	3	6
Shale, red and gray laminated, hard	402	6	414		11	6
Shale, red with streaks of green	414		424		10	
Shale, red and green laminated	424		426		2	
Shale, red	426		432		6	
Shale, red and green laminated	432		461		29	
Shale, gray, hard	461		469		8	
Shale, black	469		475		6	
Shale, gray, hard, sandy	475		480		5	
Shale, dark, hard	480		487	6	7	6
Shale, red	487	6	488			6
Shale, red and green laminated	488		488	6		6
Cumnock formation (Triassic):						
Shale, dark with greenish cast, hard	488	6	491	6	3	
Shale, gray, hard, sandy	491	6	493		1	6
Shale, dark with greenish cast, hard	493		508		15	
Shale, dark with red cast, hard	508		514		6	
Shale, dark, hard	514		516		2	
Sandstone and shale, hard	516		518		2	
Sandstone, medium-gray	518		519	6	1	6
Sandstone, black, hard	519	6	528	6	9	
Sandstone, gray, hard	528	6	538		9	6
Sandstone and shale, black laminated, hard	538		540		2	
Shale, black, hard	540		546		6	
Sandstone, gray, hard	546		553		7	
Shale, medium-gray	553		557		4	
Shale, medium-black	557		561	6	4	6
Shale, dark with greenish cast, hard	561	6	570		8	6
Slate, black	570		573		3	
Shale, dark with greenish cast, hard	573		587		14	
Slate, black	587		589		2	
Shale, dark with greenish cast, hard	589		606		17	
Shale, black, hard	606		607		1	
Shale, dark	607		611		4	
Shale, dark with greenish cast	611		624		13	
Shale, black	624		627		3	
Shale, dark with greenish cast	627		643		16	
Shale, black	643		646	6	3	6
Shale, dark with greenish cast	646	6	693	6	47	
Shale, black	693	6	699		5	6
Shale, dark, hard	699		855		156	
Shale, black with streaks of gray, sandy	855		900		45	
Shale, dark streaked with gray sandstone	900		911		11	
Shale, dark, with fossils	911		934	6	23	6
Shale, dark, streaks of sandstone and fossils	934	6	942		7	6
Shale, gray, hard, sandy	942		943	3	1	3
Shale, gray with dark shale streaks, hard	943	3	949	7	6	4
Slate, black	949	7	950	7	1	
Shale, dark	950	7	951	7	1	
Sandstone, gray, laminated with dark shale, hard	951	7	954	7	3	
Shale, dark with streaks of sandstone, hard	954	7	967	9	13	2
Shale, black, with fossils	967	9	978		10	3
Shale, gray, sandy	978		979	6	1	6
Slate, black, with fossils	979	6	987		7	6
Shale, dark, hard, with iron	987		987	6		6
Sandstone, gray, hard	987	6	988	9½	1	3½
Shale, dark, hard, sandy	988	9½	990	4	1	6½
Sandstone, hard, with streaks of shale	990	4	993	2	2	10
Shale, gray, hard, sandy, with fossils	993	2	995	2	2	
Coal including 3 inches bottom bone coal (Main bench, Cumnock Coal Bed)	995	2	998	3	3	1
Blackband (slate)	998	3	999	11	1	8
Coal (Lower bench, Cumnock Coal Bed)	999	11	1,001	6	1	7
Slate, black	1,001	6	1,001	10½		4½
Coal (Lower bench, Cumnock Coal Bed)	1,001	10½	1,002	6½		8
Slate, black	1,002	6½	1,004	1½	1	7
Shale, light-gray, sandy	1,004	1½	1,007	4½	3	3
Sandstone, gray	1,007	4½	1,008	5½	1	1
Shale, light-gray, sandy	1,008	5½	1,008	9½		4

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole DH A-4—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Sandstone, hard	1,008	9½	1,010	1	1	3½
Shale, light laminated, sandy	1,010	1	1,011			11
Sandstone, gray, fine-grained	1,011		1,011	3		3
Shale, light-gray laminated	1,011	3	1,012	2		11
Shale, dark with dark slate lamination	1,012	2	1,013	8	1	6
Sandstone, hard	1,013	8	1,015		1	4
Bottom of hole	1,015					

[1] In this record the term "slate" probably refers in part to fissile shale, "shale, hard" probably refers in part to claystone, "shale, sandy" probably refers in part to siltstone, and "shale, red" probably refers in part to red or brown claystone.

Drill hole DH A-5.
Location: Approximately 6,500 feet S. 40° W. of main shaft of Cumnock mine, Lee County.
Surface altitude: 290 (approximate).
Date: June 11, 1930.
Drilled for: Eavenson, Alford & Hicks.
Logged by: John Hazlett.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Surface soil:						
No core	0		16		16	
Sanford formation (Triassic):						
Shale, red, soft	16		116		100	
Shale, red, sandy	116		126		10	
Shale, red	126		206		80	
Shale, red, sandy	206		228		22	
Shale, red	228		382		154	
Shale, red, sandy	382		392		10	
Shale, red	392		465		73	
Shale, red, sandy	465		485		20	
Sandstone, gray and red laminated	485		520		35	
Shale, red	520		765		245	
Shale, red, sandy, with quartz	765		774		9	
Shale, red	774		900		126	
Bottom of hole	900					

[1] In this record the term "shale, red" probably refers to red or brown claystone, and the term "shale, red, sandy" probably refers to red or brown siltstone.

Drill hole CPDH.
Location: Approximately 6,000 feet S. 71° E. of main shaft of Cumnock mine, Chatham County (penetrates Carolina mine workings).
Surface altitude: 262.
Date: 1944.
Drilled for: Coal Products, Inc.
Logged by: Ralph T. Smith.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
River terrace deposits (Quaternary):						
Clay, sand, and gravel	0		28		28	
Sanford formation (Triassic):						
Shale, red, soft	28		42	2	14	2
Shale, gray, sandy	42	2	44	3	2	1
Shale, red, containing clay streaks	44	3	65	4	21	1
Shale, red and green variegated	65	4	89	4	24	
Shale, red, soft	89	4	99	9	10	5
Shale, red	99	9	158		58	3
Shale, gray, sandy	158		166	2	8	2
Shale, red, sandy	166	2	210	4	44	2
Shale, red and green variegated	210	4	232	9	22	5
Shale, gray and green variegated	232	9	249	10	17	1
Cumnock formation (Triassic):						
Sandstone, gray	249	10	260	2	10	4
Shale, dark-gray	260	2	288	5	28	3
Siltstone, dark-gray	288	5	310	6	22	1

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole CPDH—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Siltstone, dark-gray, containing shale streaks	310	6	315	7	5	1
Shale, dark-gray, sandy	315	7	331		15	5
Shale, dark	331		334		3	
Shale, gray, hard, silty	334		354	5	20	5
Shale, dark	354	5	359	7	5	2
Shale, gray, hard	359	7	363	8	4	1
Sandstone	363	8	364	6		10
Shale, gray, hard	364	6	366	2	1	8
Sandstone, shaly	366	2	367	1		11
Shale, gray, hard	367	1	378	2	11	1
Slate, black	378	2	382		3	10
Shale, gray, hard	382		388		6	
Slate, black	388		394	3	6	3
Shale, gray, hard	394	3	401	2	6	11
Shale, black	401	2	406	8	5	6
Shale, gray, hard	406	8	414	2	7	6
Slate, black	414	2	419	11	5	9
Shale, gray, hard	419	11	440	6	20	7
Shale, black	440	6	448	8	8	2
Shale, gray, hard	448	8	465	8	17	
Shale, dark	465	8	480	11	15	3
Shale, dark-gray, hard	480	11	491	1	10	2
Shale, black	491	1	500	4	9	3
Shale, dark	500	4	542	9	42	5
Shale, dark-gray	542	9	556	11	14	2
Shale, black	556	11	563	9	6	10
Shale, dark	563	9	568		4	3
Shale, dark-gray	568		589		21	
Shale, black	589		709	5	120	5
Shale, gray, sandy	709	5	710	1		8
Shale, dark	710	1	712	1	2	
Shale, dark-gray	712	1	714	4	2	3
Shale, black	714	4	716		1	8
Sandstone, shaly	716		720		4	
Shale, black	720		745		25	
Shale, black, with silt spots	745		753	8	8	8
Coke and *Coal* (Top bench, Cumnock Coal Bed)	753	8	754	3		7
Shale, gray, sandy	754	3	758	1	3	10
Coal (Main bench, Cumnock Coal Bed)	758	1	759	4	1	3
Core lost. This interval is probably mostly coal	759	4	761	7	2	3
Shale, gray, sandy	761	7	762	10	1	3
Blackband	762	10	763	1		3
Coal (Lower bench, Cumnock Coal Bed)	763	1	763	3		2
Blackband	763	3	764	10	1	7
Coal (Lower bench, Cumnock Coal Bed)	764	10	764	11		1
Blackband	764	11	765	1		2
Shale, dark	765	1	765	5		4
Shale, coaly	765	5	765	7		2
Shale, gray	765	7	766	1		6
Shale, dark	766	1	766	6		5
Shale, gray, sandy	766	6	767	11	1	5
Shale, light, sandy	767	11	772	3	4	4
Sandstone, shaly	772	3	779	6	7	3
Bottom of hole	779	6				

[1] In this record the term "slate" probably refers in part to fissile shale, "shale, gray, sandy" probably refers to siltstone, "shale, gray, hard" probably refers in part to gray claystone, and "shale, red" probably refers in part to red or brown claystone.

Drill hole BMDH D-1.
Location: Approximately 4,900 feet S. 67° W. of main shaft of Cumnock mine, Chatham County.
Surface altitude: 227.
Date: September 27, 1944.
Drilled for: U. S. Bureau of Mines.
Logged by: R. A. Laurence, U. S. Geological Survey (coal descriptions by Bureau of Mines).

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
River terrace deposits (Quaternary):						
No core	0		32		32	
Sanford formation (Triassic):						
Shale, red-brown, mottled with gray, few limestone pebbles	32		58		26	
No core	58		71		13	
Shale as above	71		90		19	

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH D-1—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Sandstone, gray, fine-grained, micaceous	90		95		5	
Siltstone, red-brown, with beds of gray siltstone and gray fine-grained sandstone	95		104	6	9	6
Shale, red-brown as above	104	6	114		9	6
Siltstone as above	114		118	6	4	6
Shale, red-brown as above	118	6	137		18	6
Shale and siltstone, alteration of beds like the above. Gray micaceous fine-grained sandstone 142 ft to 144 ft 6 in, 149 ft to 151 ft, 162 ft to 164 ft, 178 ft 6 in to 180 ft	137		185	7	48	7
Siltstone, mottled red-brown and greenish-gray; grades downward into fine-grained sandstone. Fault at 199 ft 6 in dips 70°, opposite to bedding	185	7	201	8	16	1
Siltstone, red-brown and gray banded, micaceous, dips 15°	201	8	208		6	4
Shale, red-brown, with pebbles of limestone	208		234		26	
Siltstone, gray, mottled with red, contains pebbles of gray and red shale and siltstone	234		237	6	3	6
Shale, red-brown, large irregular patches of gray slightly calcareous shale, also small limestone pebbles	237	6	251		13	6
Siltstone, gray mottled with patches of red brown	251		255	6	4	6
Shale (and some red-brown micaceous siltstone, red-brown; with small limestone pebbles. (Gray micaceous siltstone at 270 ft to 270 ft 7 in)	255	6	280		24	6
Siltstone, gray, slightly calcareous; top 2 feet mottled with red-brown patches	280		286		6	
Shale, mottled greenish-gray and red-brown; with pebbles of limestone; grades into siltstone in lower foot; ⅛-in. limestone bedding at bottom dips 20°	286		317	2	31	2
Siltstone, gray, micaceous	317	2	320		2	10
Siltstone, gray, slightly mottled with red-brown; limestone pebbles	320		332		12	
Siltstone, gray, micaceous	332		337		5	
Siltstone, gray, mottled red-brown in places	337		348	6	11	6
Cumnock formation (Triassic):						
Shale, dark-gray, with few beds of gray micaceous siltstone	348	6	364		15	6
Shale, black, pyritic, with fine-grained calcareous siltstone and a diabase dike	364		370	10	6	10
Shale, gray, very calcareous; with pebbles of limestone; upper part pyritic	370	10	373	2	2	4
Shale and siltstone, interbedded, light-gray	373	2	381	7	8	5
Sandstone, gray, banded, fine-grained; dip 12°	381	7	384	4	2	9
Shale, dark-gray, calcareous	384	4	385	2		10
Sandstone, dark-gray, with thin limestone bands and very thin coaly bands	385	2	389	4	4	2
Shale, medium-gray, non-calcareous, pyritic	389	4	390	6	1	2
Sandstone, gray, fine-grained	390	6	393		2	6
Shale, dark-gray, with beds of siltstone; fine-grained calcareous sandstone bands at base	393		405	1	12	1
Sandstone, coarse-grained, micaceous, calcareous; dip 10°	405	1	407	1	2	
Shale, dark-gray, with bands of fine-grained calcareous sandstone; dip 15°	407	1	416	2	9	1
Shale, black, ½-in. limestone bed with pyrite band at top and bottom at 416 ft. 10 in.; dip 15°	416	2	417	8	1	6
Limestone, fine-grained	417	8	417	11		3
Diabase dike	417	11	420	11	3	

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH D-1—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Sandstone, gray, fine- to medium-grained, micaceous; with interbedded dark-gray shale and siltstone; some beds strongly banded; dip 18°	420	11	429	7	8	8
Shale, dark-gray to black, pyritic; with thin calcite veins; calcareous gray siltstone at 433 ft to 435 ft 6 in.	429	7	439	2	9	7
Shale, dark-gray, with bands of light-gray siltstone; dip 16°	439	2	446	7	7	5
Shale, medium- to dark-gray, calcareous; thin calcite veins on fractures and bedding; pyrite nodules; dip 15°	446	7	494		47	5
Shale, black, non-calcareous; thin calcite veins on bedding	494		495	5	1	5
Shale, black, calcareous, with thin calcite veins	495	5	497		1	7
Shale, light- to medium-gray, calcareous	497		504		7	
Shale, black, non-calcareous, with calcite veins	504		505	1	1	1
Shale, black, calcareous, with calcite veins	505	1	507	11	2	10
Shale, black, non-calcareous, with calcite veins	507	11	509	1	1	2
Shale, black, calcareous, with calcite veins	509	1	510	1	1	
Shale, medium-gray, slightly calcareous	510	1	514	11	4	10
Shale, black, calcareous; fossil fragments	514	11	518	7	3	8
Shale, black, non-calcareous, fossil fragments	518	7	520	10	2	3
Shale, medium-gray, calcareous	520	10	528	1	7	3
Shale, black, slightly calcareous; with calcite veins and fossil fragments	528	1	542	10	14	9
Shale, black, non-calcareous; with calcite veins and fossil fragments	542	10	543	11	1	1
Shale, dark-gray to black, calcareous; with calcite veins; dip 12° to 15°	543	11	728		184	1
Shale, dark-gray to black, calcareous; with hard limy nodules and beds; fossil fragments and thin calcite veins	728		743	6	15	6
Shale, black, calcareous, with calcite veins	743	6	745		1	6
Shale, black, non-calcareous, with calcite veins	745		747	1	2	1
Shale, black, calcareous, with calcite veins	747	1	753	6	6	5
Shale, black, non-calcareous, with calcite veins	753	6	756	1	2	7
Shale, black, calcareous, with calcite veins; pyrite nodules in lower part	756	1	759	1	3	
Shale, black, non-calcareous, pyritic; with calcite veins	759	1	760	8	1	7
Diabase dike	760	8	762	6	1	10
Shale, black, non-calcareous except upper 1 ft 6 in.; with thin calcite veins	762	6	766	4	3	10
Diabase dike	766	4	767			8
Shale, black, non-calcareous (locally slightly calcareous) pyritic, with thin calcite veins and small limestone pebbles; fault at 776 ft 6 in., dips 60° (in direction of bedding) with thin veins of pyrite and calcite	767		778	7	11	7
Diabase dike	778	7	784	7	6	
Shale, black, non-calcareous; with hard light-gray limy beds and nodules	784	7	794		9	5
Shale, black, non-calcareous; many highly polished slickensided bedding planes and fractures	794		807	2	13	2
Shale, black, calcareous	807	2	808	2	1	
Shale, black, non-calcareous	808	2	814	10	6	8
Shale, dark-gray to black, calcareous, with beds of light-gray, hard, dense limestone	814	10	847	6	32	8

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH D-1—Continued

Description	Depth from surface: From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
Cumnock formation (Triassic)—Con.						
Shale, black, non-calcareous	847	6	848			6
Shale, dark-gray to black, calcareous	848		849	5	1	5
Shale, black, non-calcareous (locally calcareous) with thin calcite veins; crumpled (fault zone) at 850 ft 2 in	849	5	858	4	8	11
Shale, dark-gray to black, calcareous	858	4	862	4	4	
Diabase dike	862	4	864	6	2	2
Shale, black, calcareous	864	6	867	4	2	10
Diabase dike	867	4	867	10		6
Shale, black, calcareous, pyritic	867	10	869	8	1	10
Diabase dike	869	8	870	4		8
Shale, black, slightly calcareous, pyritic	870	4	873	6	3	2
Dark-gray, finely crystalline igneous rock, lower contact irregular (olivine basalt)	873	6	874	1¾		7¾
Coke (Main bench, Cumnock Coal Bed); with numerous mineralized veins and thin calcareous partings on bedding planes	874	1¾	874	4½		2¾
Coke, (Main bench, Cumnock Coal Bed); horizontally banded, with numerous original fracture lines, core coherent, moderately hard, dark gray. No original coal pieces visible. One thin high ash parting, apparently remains in its original position in the bed. Finely porous. Chemical analysis C-27088 (see table 10)	874	4½	876	5½	2	1
Shale, black, non-calcareous, pyritic	876	5½	878	4	1	10½
Coke (Lower bench, Cumnock Coal Bed)	878	4	879	5	1	1
Shale, gray, non-calcareous	879	5	879	6		1
Shale, gray, medium-hard, dark streaks at top	879	6	880			6
Shale, dark fissile	880		880	3		3
Coal (Lower bench, Cumnock Coal Bed), attrital, badly broken; chemical analysis C-27087 (see table 10)	880	3	880	6¾		3¾
Coal, dirty	880	6¾	880	7¾		1
Shale, dark with small sideritic concretions	880	7¾	881	4		8¼
Shale, black, non-calcareous, highly polished slickensides	881	4	882	2		10
Sandstone, light-gray, fine- to medium-grained, banded with medium-gray micaceous siltstone	882	2	892		9	10
Shale, black, micaceous	892		893	4	1	4
Sandstone, gray, banded, with dark shaly layers and few thin coaly bands	893	4	909	6	16	2
Shale, black, with thin coaly beds and 3 in. dense hard limestone beds at 910 ft 4 in. and 912 ft 2 in	909	6	912	3	2	9
Sandstone, gray, fine-grained	912	3	912	4½		1½
Shale, gray, broken	912	4½	912	6¼		1¾
Shale, gray, fissile, darker and coaly at base	912	6¼	912	8¾		2½
Shale, bony and coaly	912	8¾	912	11½		2¾
Coal (Gulf Coal Bed), attrital, bright, badly broken but 12 in. coal recovered; finely banded; chemical analysis C-27089 (see table 10)	912	11½	915	3½	2	4
Shale, dark, fine-grained	915	3½	915	6¾		3¼
Shale, coaly and bony in alternating bands	915	6¾	915	11½		4¾
Shale, dark, fine-grained	915	11½	916	1¾		2¼
Shale, bony	916	1¾	916	2¾		1
Shale, black, with thin interbedded gray sandy beds; dip 12°	916	2¾	921	8	5	5¼
Stick-up, left in hole	921	8	922	6		10
Bottom of hole	922	6				

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH D-2.
Location: Approximately 6,000 feet S. 36° W. of main shaft of Cumnock mine, west side Deep River, Chatham County.
Surface altitude: 237.
Date: August 5, 1944.
Drilled for: U. S. Bureau of Mines.
Logged by: R. A. Laurence, U. S. Geological Survey (coal descriptions by Bureau of Mines).

Description	Depth from surface: From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
River terrace deposits (Quaternary):						
No core	0		371		371	
Sanford formation (Triassic):						
Shale, red; with small limestone pebbles throughout; bedding obscure; lower part sandy	371		396		25	
Sandstone, red; fine-grained, micaceous	396		398	6	2	6
Shale, red; as at top, with interbedded sandstone and sandy shale	398	6	470		71	6
Sandstone, red, fine-grained, micaceous	470		480		10	
Shale and sandy shale, red (small red ferruginous pebbles or concretions at 483-485 ft)	480		497		17	
Sandstone, gray, banded, fine- to medium-grained; dip 15°	497		506	6	9	6
Conglomerate, quartz pebbles (some elongated) up to ½ in	506	6	510	6	4	
Shale, gray and greenish-gray	510	6	515	6	5	
Shale, red, sandy, with few thin gray limy streaks; dip 20°	515	6	574		58	6
Shale, red, with limy pebbles and small red ferruginous pebbles or concretions	574		578		4	
Shale, red, sandy, with few thin gray limy streaks	578		601		23	
Sandstone, gray, fine-grained, with limy lenses	601		603	6	2	6
Shale, red with many light-gray limy and blue-gray shaly pebbles, and few small red ferruginous pebbles or concretions	603	6	618		14	6
Shale like next above, but with only few pebbles	618		632		14	
Sandstone, gray, banded, fine-grained, with thin calcareous bands	632		636		4	
Shale, red, sandy	636		639		3	
Conglomerate, large (up to 6 in.) pebbles of banded sandstone in shaly sandstone matrix	639		641		2	
Siltstone, red, grading downward into gray-brown, with small ferruginous pebbles or concretions; large gray sandstone pebble at 656 ft	641		658		17	
Shale, grayish-brown	658		675		17	
Sandstone, red-brown, fine-grained, shaly, with limy areas	675		685		10	
Shale, red-brown	685		694		9	
Sandstone, mottled red and greenish-gray, fine-grained	694		703		9	
Shale, red-brown, sandy, banded	703		708		5	
Sandstone, mottled red and greenish-gray, with limy bands and small red ferruginous pebbles or concretions	708		720		12	
Sandstone, gray, banded, fine-grained	720		726		6	
Siltstone, red-brown	726		729		3	
Shale, mottled red and greenish-gray, with small red ferruginous pebbles or concretions	729		737		8	
Sandstone, brown, fine-grained	737		739		2	
Shale, mottled red and greenish-gray	739		745		6	
Sandstone, gray, fine-grained, limy with red pebbles	745		747		2	
Siltstone, red-brown, with a few bands of limy sandstone	747		769		22	
Siltstone, red, interbedded with gray fine- to medium-grained sandstone, some of which is slightly calcareous	769		783		14	
Siltstone, red-brown	783		794		11	

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH D-2—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Sandstone, light-gray, fine- to medium-grained	794		798		4	
Siltstone, red-brown	798		822		24	
Shale, gray, calcareous	822		825		3	
Siltstone, red-brown, with thin bands of gray limy shale and small limestone pebbles	825		851		26	
Siltstone, red-brown mottled with large patches of fine-grained, bluish-gray sandstone, some of which is calcareous	851		886		35	
Siltstone, as above but with only a little gray	886		909		23	
Shale, blue-gray (a little of it is limy) with some interbedded red-brown siltstone in upper part; much interbedded shale and limy pebbles in lower 10 ft	909		950		41	
Shale, red-brown; includes some greenish-gray shale in lower part	950		959		9	
Cumnock formation (Triassic):						
Shale and siltstone, greenish-gray, with some interbedded dark-gray shale	959		982		23	
Shale, dark-gray	982		988		6	
Siltstone, greenish-gray	988		996	6	8	6
Diabase dike	996	6	998	6	2	
Shale, black	998	6	999			6
Shale, dark-gray, with interbedded fine-grained gray sandstone, some of which is limy; some black shale beds and small diabase dikes	999		1,062		63	
Shale, dark-gray to black; with calcite veins especially on faulted zones in the black shales. Also some pyrite. Most of this shale is slightly calcareous; the darker the color, the less calcareous. Diabase dike at 1,064 to 1,067 ft 3-in. gray shaly limestone at 1,359 ft. Small fossils (Posidonia, cf. Emmons 1,856 report) at 1,162 ft and 1,354 ft	1,062		1,401		339	
Shale, black, with large patches of hard fine-grained limy sandstone	1,401		1,415		14	
Diabase dike	1,415		1,417		2	
Shale, black	1,417		1,418		1	
Diabase dike	1,418		1,433		15	
Shale, dark-gray to black, slightly calcareous	1,433		1,465		32	
Shale, like next above but with thin interbedded hard gray limy bands	1,465		1,468		3	
Shale, dark-gray to black, slightly calcareous	1,468		1,498	6	30	6
Siltstone, shale and fine-grained sandstone, slightly pinkish, light-gray, thin-bedded, medium-hard tracks and trails on bedding surfaces	1,498	6	1,507		8	6
Coke (Top bench, Cumnock Coal Bed), dull-black, soft, lightweight. Shoes a few recognizable pieces of slightly altered coal on some fracture surfaces. Chemical analysis C-24682 (see table 10)	1,507		1,508		1	
Shale, medium-dark, with light siltstone laminae, ironstone concretions	1,508		1,508	4½		4½
Shale, medium-gray, medium-hard	1,508	4½	1,508	11		6½
Shale, light-gray, medium-soft, easily slacking, with silty ironstone concretions and a few medium-gray shale laminae	1,508	11	1,509	10½		11½
Shale, thin-bedded, rashy, few thin vitrain streaks in lower part	1,509	10½	1,510	1		2½
Coal (Main bench, Cumnock Coal Bed), bright, very thin-banded and attrital, broken into 1 inch biscuits	1,510	1	1,510	9		8
Coal (Main bench, Cumnock Coal Bed), very bright, microlaminated and attrital with longitudinal cleats and abundant horizontal fractures. Chemical analysis C-24683. Coal extremely friable but nearly all in place, practically complete recovery	1,510	9	1,513	½	2	3½

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH D-2—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Coal (Main bench, Cumnock Bed), breaking into biscuits, probably high ash	1,513	½	1,513	3		2½
Shale, black, and dark shale variably soft and hard, partly broken, irregular	1,513	3	1,514	5	1	2
Shale, black	1,514	5	1,514	10		5
Shale, black, fine-grained, soft and medium-hard, with irregular small concretions and undulating thin calcareous laminae	1,514	10	1,515	8		10
Coal (Lower bench, Cumnock Coal Bed), attrital, bright, badly broken and friable, fine-banded, near complete recovery	1,515	8	1,516	3		7
Shale, black, with small gray, silty lenses and fossils	1,516	3	1,516	6½		3½
Shale, light-gray, sandy and medium-gray, alternating irregularly with macerated plant fragments	1,516	6½	1,519		2	5½
Shale, dark	1,519		1,519	2		2
Coal (Lower bench, Cumnock Coal Bed), finely-laminated, attrital, high ash, dull luster	1,519	2	1,519	10½		8½
Coal or coaly shale (Lower bench, Cumnock Coal Bed), very high ash, attrital	1,519	10½	1,520	4½		6
Shale, interbedded black and gray	1,520	4½	1,528	5	8	½
Shale and sandstone, interbedded, gray	1,528	5	1,546		17	7
Shale, black	1,546		1,546	6		6
Bottom of hole	1,546	6				

Drill hole BMDH E-1.
Location: Approximately 7,800 feet S. 72° W. of main shaft of Cumnock mine, near Chatham Brick & Tile Co., Chatham County.
Surface altitude: 234.
Date: October 28, 1944.
Drilled for: U. S. Bureau of Mines.
Logged by: R. A. Laurence, U. S. Geological Survey (coal descriptions by Bureau of Mines).

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Surface soil:						
No core	0		398		398	
Sanford formation (Triassic):						
Shale, brownish-red, non-calcareous, with interbedded green fine-grained sandstone and slightly calcareous gray siltstone	398		415		17	
No core	415		475		60	
Shale, dark-brown, with mottled brown and green shale. Interbedded green fine-grained sandstone in upper part; dip 10°	475		521	6	46	6
Cumnock formation (Triassic):						
Shale, gray to black, and gray siltstone; slightly calcareous. Red shale at 525 ft 7 in. to 526 ft. Highest black shale at 536 ft	521	6	543	8	22	2
Shale, black to gray, calcareous; with interbedded fine-grained sandstones	543	8	563	6	19	10
Siltstone, gray, with some interbedded black shale; dip 10°	563	6	587	6	24	
Shale, black, non-calcareous; with some interbedded gray siltstone. Dikes at 594 ft to 595 ft 6 in., 614 ft to 615 ft 4 in	587	6	618		30	6
Shale, dark-gray to black, calcareous; with thin calcite veins, fault at 758 ft 6 in., dips 70° in same direction as bedding. Several minor fault zones near this. Faulted and crumpled zone at 770 ft to 772 ft	618		810		192	4

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH E-1—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Shale, dark-gray to black, calcareous, with thin bands and nodules of limestone. Faulted and crumpled zone at 874 ft to 874 ft 6 in. Faulted zone with highly polished slickensides at 888 ft. Dense, hard, slightly calcareous nodule at 897 ft 7 in. to 898 ft	810		900		90	
Shale, black, calcareous, with a few thin calcite veins, dip 10°	900		937		37	
Shale, black, calcareous, with dense limestone nodules and a few thin limestone bands	937		937	4		4
Sandstone, calcareous, fine-grained, banded	937	4	974	11¾	37	7¾
Shale, gray, carbonaceous, medium- and wavy-banded, slickensided, medium-hard	974	11¾	975	1¾		2
Shale, coaly, dark, nearly black, medium hard	975	1¾	975	3¾		2
Coal (Main bench, Cumnock Coal Bed; chemical analysis C–28759), bright, slickensided and cleated, but coherent, high ash, medium-banded	975	3¾	975	4¼		½
Coal (Main bench, Cumnock Coal Bed; chemical analysis C–28759), as above, thinly banded, dull lustre	975	4¼	975	7¼		3
Coal (Main bench, Cumnock Coal Bed; chemical analysis C–28759), as above, badly broken, probably less ash	975	7¼	975	9¼		2
Coal (Main bench, Cumnock Coal Bed; chemical analysis C–28759), attrital, thin, microbanded, broken in part	975	9¼	975	11		1¾
Coal (Main bench, Cumnock Coal Bed; chemical analysis C–28759), bright, pulverized, (recovery may be nearly complete)	975	11	976	8½		9½
Coal (Main bench, Cumnock Coal Bed; chemical analysis C–28759), bright, largely attrital, breaks easily, especially on cleavage plane slightly inclined from the bedding plane, vertical cleats prominent. Coal pulverized, few large pieces	976	8½	977	8¼		11¾
Coal (Main bench, Cumnock Coal Bed; chemical analysis C–28759), bright, attrital, few thin vitrain bands, moderately pyritic	977	8¼	977	9		¾
Shale, dark-gray to black, dense, hard, many blebs of vitrain; occasional streaks of grayer shale	977	9	979	6	1	9
Coal (Lower bench, Cumnock Coal Bed; chemical analysis C–28760), bright, sparsely banded and attrital, breaks easily (but core recovery good)	979	6	980	1		7
Coal (Lower bench, Cumnock Coal Bed, chemical analysis C–28760), bright, attrital, prominent cleats, breaks easily (coherent core)	980	1	981	¾		11¾
Coal (Lower bench, Cumnock Coal Bed, chemical analysis C–28760), attrital, bright, high ash, pyrite	981	¾	981	2		1¼
Shale, dark, coaly	981	2	981	4		2
Shale, medium-gray	981	4	981	5½		1½
Shale, gray, grading to dark with small light lenses	981	5½	981	8		2½
Coal (Lower bench, Cumnock Coal Bed, chemical analysis C–28761), bright, thin banded attrital	981	8	981	10¼		2¼
Coal (Lower bench, Cumnock Coal Bed, chemical analysis C–28761), high ash and pyrite, canneloid, attrital, dull lustre	981	10¼	981	11¼		1
Coal (Lower bench, Cumnock Coal Bed, chemical analysis C–28761), bright, attrital, broken moderately, fine-banded	981	11¼	982	¼		1
Coal (Lower bench, Cumnock Coal Bed, chemical analysis C–28761), pulverized, bright, attrital, moderately high ash (badly mudded, but washed out before analyses)	982	¼	983	½	1	¼

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH E-1—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Shale, light to dark-gray (looks black on outside, interwoven light and dark beds, wavy bedding, concretions, occasional blebs of vitrain, slickensides; beds become thinner near bottom)	983	½	983	6		5½
Shale, black	983	6	985		1	6
Sandstone, gray, fine-grained, calcareous, and brown non-calcareous, interbedded	985		991		6	
Shale, black, non-calcareous	991		995		4	
Sandstone, gray, fine-grained, banded, non-calcareous; dip 10°	995		1,008		13	
Shale, black, non-calcareous, limestone nodule at 1008 ft to 1008 ft 10 in.	1,008		1,010	4	2	4
Shale, coaly, shiny, contains lenses of coal and blebs of vitrain	1,010	4	1,010	9		5
Shale, coaly as above, contains calcite facings and blebs of vitrain	1,010	9	1,011			3
Coal (Gulf Coal Bed, chemical analysis C–28940), bright, attrital, cleated, easily broken, in part high ash with calcareous and pyritic kaolinite lenticles	1,011		1,012	½	1	½
Coal (Gulf Coal Bed, chemical analysis C–28940), badly broken, thinly bedded, few large pieces, bright, low ash	1,012	½	1,012	4		3½
Shale, dark-gray, grading down to light-gray, coaly shale at top, few blebs vitrain	1,012	4	1,012	9¾		5¾
Coal (Gulf Coal Bed, chemical analysis C–28940), shaly, bright, attrital and microbanded, moderately cleated but with thin calcite facings	1,012	9¾	1,013	¼		2½
Sandstone, fine-grained, non-calcareous, banded	1,013	¼	1,020		6	11¾
bottom of hole	1,020					

Drill hole BMDH E-2.
Location: Approximately 8,600 feet S. 46° W. of main shaft of Cumnock mine, Chatham County.
Surface altitude: 260.
Date: October 7, 1944.
Drilled for: U. S. Bureau of Mines.
Logged by: R. A. Laurence, U. S. Geological Survey (coal descriptions by Bureau of Mines).

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
River terrace deposits (Quaternary):						
Not cored	0		924		924	
Sanford formation (Triassic):						
Siltstone (with some shale), red-brown with small bluish-gray patches; also pebbles of limestone	924		1,023		99	
Siltstone as above with irregular beds of fine-grained gray sandstone	1,023		1,024	10	1	10
Siltstone, red-brown with bluish-gray patches and pebbles of limestone. Micaceous	1,024	10	1,043	6	18	8
Sandstone, red-brown, fine- to medium-grained, micaceous, with some interbedded red shale; lower 5 in. conglomerate	1,043	6	1,049		5	6
Siltstone, red-brown, micaceous; with irregularly shaped limestone areas (not pebbles)	1,049		1,058	7	9	7
Shale, red-brown, with limestone pebbles	1,058	7	1,068	1	9	6
Siltstone, red-brown, micaceous, limetone patches	1,068	1	1,078	7	10	6
Sandstone, gray, fine-grained, micaceous	1,078	7	1,079	8	1	1
Siltstone and shale, red-brown, micaceous, with irregularly shaped patches of limestone	1,079	8	1,090		10	4

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH E-2—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Siltstone, red-brown, micaceous	1,090		1,099	10	9	10
Conglomerate, red-brown, poorly-rounded, quartz pebbles, in micaceous siltstone matrix	1,099	10	1,102		2	2
Siltstone, gray and red-brown, micaceous	1,102		1,107	1	5	1
Shale, red-brown	1,107	1	1,109		1	11
Siltstone, red-brown, micaceous; 3 in. gray fine-grained sandstone at 1,113 ft. 6 in.; dip 15°	1,109		1,115	6	6	6
Shale, mottled red-brown and gray	1,115	6	1,117	6	2	
Siltstone, red-brown, micaceous, limestone pebbles	1,117	6	1,137	1	19	7
Conglomerate, red-brown, pebbles of limestone and red-brown siltstone in red shaly matrix. Many slickensided fractures and beds	1,137	1	1,144		6	11
Siltstone, red-brown (mottled gray locally), micaceous. Limestone pebbles. Some interbedded red-brown shales	1,144		1,171		27	
Siltstone, red-brown, micaceous	1,171		1,185	6	14	6
Sandstone, gray, fine- to medium-grained, micaceous	1,185	6	1,187		1	6
Shale, red-brown	1,187		1,188		1	
Siltstone, red-brown, micaceous	1,188		1,189	10	1	10
Siltstone, mottled red-brown and bluish-gray ½ in. calcareous band at base, dip 35°	1,189	10	1,204		14	2
Siltstone, red-brown, micaceous; with little interbedded red shale, limestone pebbles in lower 2 ft	1,204		1,222	4	18	4
Siltstone, bluish-gray, micaceous	1,222	4	1,228	1	5	9
Siltstone, red-brown and bluish-gray mottled, micaceous; some of gray areas are calcareous	1,228	1	1,237		8	11
Siltstone, red-brown, micaceous; with some gray siltstone beds and some gray and red-brown beds	1,237		1,290	6	53	6
Siltstone, bluish-gray	1,290	6	1,298	2	7	8
Shale, red-brown	1,298	2	1,299	5	1	3
Siltstone, bluish-gray, mottled reddish patches	1,299	5	1,322	5	23	
Shale, dark-gray, medium-grained, non-calcareous	1,322	5	1,330		7	7
Shale, medium-gray, slightly calcareous; with small hard limy pebbles and few plant fragments	1,330		1,330	8		8
Siltstone, gray, medium-grained, micaceous	1,330	8	1,334	6	3	10
Siltstone and shale, mottled red and gray	1,334	6	1,341	10	7	4
Siltstone, mottled red and gray, with small hard limy pebbles or concretions; micaceous	1,341	10	1,347	2	5	4
Siltstone, gray, micaceous	1,347	2	1,351	5	4	3
Shale and siltstone, red and gray mottled, with thin limy bands; dip 20°	1,351	5	1,356		4	7
Siltstone, gray, micaceous; with limy pebbles. Grades into next below	1,356		1,356	2		2
Sandstone, light-gray, fine-grained; lightly banded; with small rounded limy areas (pebbles); dip 20°	1,356	2	1,364		7	10
Sandstone, gray, strongly banded and crossbedded; dip 20°	1,364		1,368	6	4	6
Shale, mottled red and brown, with interbedded siltstone, several crumpled and slickensided zones. Calcareous pebbles in some beds; 3 in. hard calcareous bed at base	1,368	6	1,390	7	22	1
Cumnock formation (Triassic):						
Shale, black	1,390	7	1,393		2	5
Siltstone, dark-gray, micaceous. Dark carbonaceous band at base	1,393		1,397	4	4	4
Siltstone, very calcareous. Grades into next below	1,397	4	1,398	8	1	4
Siltstone, upper part slightly calcareous. Sandstone pebbles and "dikes" on vertical fractures, dip 15°	1,398	8	1,402	8	4	
Shale, medium- to dark-gray, non-calcareous	1,402	8	1,403	7		11
Shale, black, non-calcareous	1,403	7	1,405	7	2	
Shale, black, calcareous	1,405	7	1,406	1		6

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH E-2—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Limestone, fine-grained	1,406	1	1,408	6	2	5
Shale and siltstone, medium- to dark-gray, non-calcareous	1,408	6	1,419	11	11	5
Coal, shaly, pyritic, many thin calcite veins; dip 12°	1,419	11	1,420			1
Shale, black, non-calcareous	1,420		1,424	5	4	5
Siltstone and shale, dark-gray (with very fine-grained diabase dikes?) non-calcareous	1,424	5	1,431	7	7	2
Shale, black, non-calcareous	1,431	7	1,435	5	3	10
Shale, dark-gray, non-calcareous, with interbedded siltstone	1,435	5	1,442	10	7	5
Siltstone, gray banded, micaceous; many beds calcareous, others non-calcareous; dip 15°	1,442	10	1,447		4	2
Shale, black, non-calcareous, with interbedded medium- to dark-gray shale and siltstone; dip 13°	1,447		1,450	6	3	6
Siltstone, light-gray, with interbedded dark-gray shale, and fine-grained sandstone. Some bands slightly calcareous; dip 15°	1,450	6	1,462	1	11	7
Diabase dike, very fine-grained	1,462	1	1,463	8	1	7
Shale, black, non-calcareous	1,463	8	1,464	6		10
Shale, black, calcareous; dip 11°	1,464	6	1,464	11		5
Shale, black, non-calcareous	1,464	11	1,466	4	1	5
Shale, black, calcareous	1,466	4	1,468	10	2	6
Shale, black, non-calcareous (locally slightly calcareous)	1,468	10	1,473	2	4	4
Limestone	1,473	2	1,473	5		3
Shale, dark-gray to black, calcareous, with many thin irregular calcite veins at 1,482 ft. 6 in. to 1,491 ft, 1,510 to 1,520 ft. A few pyrite nodules; dip 10°	1,473	5	1,522	7	49	2
Shale, black, non-calcareous	1,522	7	1,524	4	1	9
Shale, black, calcareous	1,524	4	1,525	5	1	1
Shale, medium- to dark-gray, non-calcareous	1,525	5	1,526	2		9
Shale, medium- to dark-gray, calcareous	1,526	2	1,531	6	5	4
Shale, black, calcareous	1,531	6	1,534	5	2	11
Shale, black, non-calcareous	1,534	5	1,536	1	1	8
Shale, dark gray, calcareous. Normal fault at 1,536 ft. 6 in. dip 60° in direction of beds	1,536	1	1,543	8	7	7
Shale, black, calcareous	1,543	8	1,546	2	2	6
Shale, black, non-calcareous	1,546	2	1,547	5	1	3
Shale, black, calcareous	1,547	5	1,547	11		6
Shale, dark-gray, calcareous	1,547	11	1,555	6	7	7
Shale, black, calcareous	1,555	6	1,556	8	1	2
Shale, black, non-calcareous	1,556	8	1,558		1	4
Shale, dark-gray to black, calcareous; ¼ in. limestone band at 1,561 ft 6 in. Scattered pyrite cubes at 1,564 ft 5 in. to 1,565 ft 7 in.; dip 20°	1,558		1,567		9	
Shale, black, calcareous, with calcite veins; dip 20°	1,567		1,575		8	
Shale, dark-gray to black, calcareous (some beds are probably argillaceous limestone). Several minor faults, dipping 70° to 75° especially between 1,585 and 1,600 ft; dip 10° to 15°	1,575		1,701	7	126	7
Shale, black, calcareous; with large hard limy nodules; dip 12°	1,701	7	1,715		13	5
Shale, black, calcareous, with few thin limestone bands and pyrite nodules; dip 12°; several calcite veined faults	1,715		1,772	7	57	7
Shale, black, non-calcareous	1,772	7	1,773	4		9
Shale, black, calcareous, 3 in. dense hard limestone nodule at 1,776 ft 8 in	1,773	4	1,779	5	6	1
Shale, black, non-calcareous	1,779	5	1,783	4	3	11
Shale, black, calcareous	1,783	4	1,786	11	3	7
Shale, black, non-calcareous, with thin limestone bands	1,786	11	1,788	10	1	11
Shale, black, mostly non-calcareous; with a large limy nodule at 1,794 ft	1,788	10	1,846		57	2
Shale, black, calcareous, with thin limestone bands and irregular limestone stringers. Fault dipping 40°, in direction of bedding at 1,848 ft 6 in	1,846		1,869		23	
Shale, dark carbonaceous, hard, irregularly bedded, with blebs of coal	1,869		1,877	10	8	10

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH E-2—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Shale, nearly black, carbonaceous, hard, few thin calcareous streaks, blebs of coal	1,877	10	1,878	4¼		6¼
Shale, dark, soft, flaky, coal streaks	1,878	4¼	1,878	6		1¾
Coal (Top bench, Cumnock Bed), high ash, banded, pulverized in coring	1,878	6	1,878	10		4
Underclay, dark, hard, rough fractures with slickensides	1,878	10	1,878	11¼		1¼
Underclay, gray, silty, medium-hard, slightly calcareous	1,878	11¼	1,879	2¼		3
Shale, gray banded	1,879	2¼	1,882	9	3	6¾
Shale, black	1,882	9	1,886	9¾	4	¾
Shale, gray, plastic	1,886	9¾	1,886	11¾		2
Shale, gray, medium-hard	1,886	11¾	1,887	1		1¼
Coal (Main bench, Cumnock Coal Bed, chemical analysis C-27572, see table 10), impure, dull, moderately coherent	1,887	1	1,887	2¾		1¾
Coal (main bench, Cumnock Coal Bed), very friable, fine-banded, so tender no pieces obtained from sectioning, recovery good, coal held in place by mud jacket from drill (mud washed out of sample before chemical analysis). (Chemical analysis C-27572.) (See table 10)	1,887	2¾	1,888	6	1	3¼
Coal (Main bench, Cumnock Coal Bed), very finely pulverized, including moderate amount of fusian, largest fragments generally held together by fusian bands of medium thickness	1,888	6	1,890	½	1	6½
Shale, dark, medium-hard with small blebs and streaks of coal	1,890	½	1,891	11	1	10½
Coal (Lower bench, Cumnock Coal Bed), high ash, bright, moderately cleated, attrital to fine-banded with small shaly lenses. Chemical analysis C-28506 (see table 10)	1,891	11	1,892	8		9
Coal (Lower bench, Cumnock Coal Bed), attrital as above, frozen to underclay below	1,892	8	1,892	8½		½
Shale, black, carbonaceous	1,892	8½	1,893			3½
Shale, gray, banded	1,893		1,896	9	3	9
Shale, dark pyritic with blebs of coal	1,896	9	1,897	½		3½
Shale, coal, rashy, broken	1,897	½	1,897	1		½
Coal (Lower bench, Cumnock Coal Bed), high ash, thin- and medium-banded, bright, lower ½ in. attrital and frozen to shale below	1,897	1	1,897	6		5
Shale, dark, medium-banded with a few blebs of coal	1,897	6	1,897	8		2
Shale, fine-grained, highly organic	1,897	8	1,898	10	1	2
Sandstone, light-gray, fine-grained with interbedded black shale	1,898	10	1,925		26	2
Shale, black with occasional coal partings	1,925		1,929	5	4	5
Shale, gray, slightly carbonaceous, medium-hard	1,929	5	1,929	9¼		4¼
Shale, black with gray lenses	1,929	9¼	1,929	11		1¾
Shale, black, coaly, broken	1,929	11	1,930	1¾		2¾
Coal (Gulf Coal Bed), high ash, pyritic, medium-banded, bright	1,930	1¾	1,930	4¼		2½
Shale, black, coaly, broken	1,930	4¼	1,930	5¼		1
Shale, dark with blebs of coal becoming grayer toward base	1,930	5¼	1,930	9¼		4
Coal (Gulf Coal Bed), shaly, attrital and high ash grading to coarser texture below	1,930	9¼	1,930	11		1¾
Coal (Gulf Coal Bed), high ash, pyritic, thin- and medium-banded, bright	1,930	11	1,931	3		4
Coal (Gulf Coal Bed), high ash, attrital and microbanded	1,931	3	1,931	6		3
Shale and sandstone, gray, banded	1,931	6	1,934	8	3	2
Coal	1,934	8	1,934	9		1
Shale and sandstone	1,934	9	1,936	8	1	11
Bottom of hole	1,936	8				

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH 1.
Location: Approximately 2,800 feet N. 71° W. of main shaft of Cumnock mine, west side Deep River, Chatham County.
Surface altitude: 224.
Date: April 1945.
Drilled for: U. S. Bureau of Mines.
Logged by: F. K. McIntosh, U. S. Bureau of Mines.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Alluvium (Quaternary):						
Overburden	0		37		37	
Pekin formation (Triassic):						
Diabase	37		66		29	
Shale, mottled brown	66		73		7	
Shale, mottled brown and gray	73		86		13	
Shale, mottled brown, and siltstone, gray	86		106		20	
Shale, mottled brown	106		116		10	
Bottom of hole	116					

[1] In this record the term "shale" probably refers in part to claystone.

Drill hole BMDH 2.
Location: Approximately 8,200 feet S. 60° W. of main shaft of Cumnock mine, Chatham County.
Surface altitude: 247.
Date: August 1945.
Drilled for: U. S. Bureau of Mines.
Logged by: F. K. McIntosh, U. S. Bureau of Mines.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Surface soil:						
Overburden	0		6		6	
Sanford formation (Triassic):						
Shale, brown	6		146		140	
Shale, brown and gray	146		157		11	
Sandstone, gray, coarse-grained, micaceous, porous	157		180		23	
Shale, brown	180		196		16	
Sandstone, gray, coarse-grained, micaceous	196		202		6	
Shale, brown, with small irregular masses of gray sandstone; thin-bedded to massive	202		256		54	
Shale and siltstone, brown	256		290		34	
Shale, brown	290		312		22	
Siltstone, brown	312		320		8	
Shale, brown mottled	320		325		5	
Shale, brown, occasional black (carbonaceous?) coating on fracture planes	325		365		40	
Shale, gray, black, fractures nearly vertical. Coarse-grained sandstone at 379 ft 6 in	365		387		22	
Sandstone and siltstone, dark-gray	387		393		6	
Diabase, much of it with pockets of loose granular material; badly fractured in part	393		539		146	
Siltstone, blue-gray	539		543		4	
Diabase	543		547		4	
Siltstone, blue-gray	547		564		17	
Diabase	564		571		7	
Shale, blue-gray	571		585		14	
Shale, brown	585		587		2	
Siltstone, gray, with small irregular masses of white lime	587		609		22	
Shale, brown and gray	609		633		24	
Shale to siltstone to sandstone, brown	633		653		20	
Shale and siltstone, brown	653		673		20	
Shale, brown and brown-mottled	673		707		34	
Siltstone to coarse-grained sandstone, gray	707		728		21	
Shale, brown	728		758		30	
Clay	758		760		2	
Shale, brown and brown mottled, mostly thin-bedded	760		783		23	
Shale, brown, interbedded with siltstone, gray	783		798		15	
Breccia, coarse, made up of brown and gray shale	798		828		30	
Shale, brown	828		830		2	
Siltstone and shale, gray	830		848		18	

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH 2—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Breccia, coarse, made up of brown and gray shale	848		866		18	
Siltstone, gray	866		872		6	
Shale, gray and brown	872		880		8	
Siltstone, gray	880		883		3	
Shale, brown and gray	883		894		11	
Cumnock formation (Triassic):						
Shale, gray, much of it thin-bedded and friable	894		914		20	
Shale, black, carbonaceous	914		916		2	
Shale, interbedded black and gray	916		924		8	
Shale, gray	924		925		1	
Shale, black, carbonaceous	925		927		2	
Shale, gray	927		943		16	
Shale, black, carbonaceous	943		946		3	
Shale, black, non-carbonaceous	946		950		4	
Siltstone, gray	950		953		3	
Shale, black, thin-bedded, non-carbonaceous	953		957		4	
Shale, gray	957		963		6	
Sandstone, gray, medium-grained, wavy bedding	963		964		1	
Shale, gray	964		967		3	
Sandstone, gray and brown, medium-grained	967		974		7	
Shale, black, thin-bedded, slightly carbonaceous	974		976		2	
Shale, gray	976		981	6	5	6
Sandstone, gray, medium-grained, micaceous	981	6	982			6
Shale, black, carbonaceous	982		989		7	
Shale, gray	989		990		1	
Shale, black, carbonaceous	990		995		5	
Diabase	995		996		1	
Diabase and black shale	996		997		1	
Shale, gray, calcite veinlets	997		1,010		13	
Shale, gray, calcareous, calcite veinlets	1,010		1,045		35	
Shale, black, carbonaceous, calcite veinlets	1,045		1,048		3	
Shale, gray	1,048		1,054		6	
Shale, black, thin-bedded, carbonaceous, calcite film on bedding planes	1,054		1,060		6	
Shale, gray, calcareous, calcite veinlets, oil on fractures	1,060		1,066		6	
Shale, black, carbonaceous, with calcite film on beddings	1,066		1,072		6	
Shale, gray, calcareous	1,072		1,081		9	
Shale, black, carbonaceous, calcareous	1,081		1,088		7	
Shale, gray, calcareous	1,088		1,104		16	
Shale, black and gray, core ground up	1,104		1,114		10	
Shale, gray, calcareous, calcite veinlets	1,114		1,144		30	
Shale, black, carbonaceous	1,144		1,148		4	
Shale, gray, calcareous	1,148		1,162		14	
Shale, black, calcareous, carbonaceous	1,162		1,166		4	
Shale, dark-gray, calcareous	1,166		1,217		51	
Shale, black, carbonaceous, calcareous	1,217		1,220		3	
Shale, gray, calcareous	1,220		1,232		12	
Shale, black, calcareous, carbonaceous	1,232		1,238		6	
Shale, gray, calcareous	1,238		1,282		44	
Shale, gray and black, calcareous, with occasional limy area	1,282		1,292		10	
Shale, black, with limy areas	1,292		1,422	10	130	10
Coaly shale (Top bench, Cumnock Coal Bed)	1,422	10	1,423	4		6
Sandstone, gray wavy bedding	1,423	4	1,427	8	4	4
Core lost (Main bench, Cumnock Coal Bed)	1,427	8	1,431	5	3	9
Shale, black	1,431	5	1,433	4	1	11
Coal (Lower bench, Cumnock Coal Bed), chemical analysis C–47760 (see table 10)	1,433	4	1,434	4	1	
Shale, black	1,434	4	1,435	2		10
Coal (Lower bench, Cumnock Coal Bed), chemical analysis C–47760 (see table 10)	1,435	2	1,435	10		8
Shale, black	1,435	10	1,437	10	2	
Shale, gray with wavy bedding	1,437	10	1,443	7	5	9
Clay	1,443	7	1,444			5
Shale, gray with wavy bedding	1,444		1,446	10	2	10
Shale, gray with wavy bedding	1,446	10	1,451	4	4	6
Sandstone, gray, wavy bedding	1,451	4	1,460	11	9	7

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH 2—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Coal (Gulf Coal Bed, chemical analysis C–47761, see table 10) crushed, but good recovery	1,460	11	1,463		2	1
Shale, black, dense	1,463		1,463	5		5
Shale, black, dense	1,463	5	1,464	8	1	3
Coal, shaly	1,464	8	1,465	5		9
Shale, black and gray, with wavy bedding	1,465	5	1,468	10	3	5
Bottom of hole	1,468	10				

[1] In this record the term "shale, brown" probably refers in part to reddish-brown claystone, and the term "shale, gray" probably refers in part to gray claystone.

Drill hole: BDH 1.
Location: Approximately 24,100 feet S. 70° W. of main shaft of Cumnock mine, east side Deep River, Lee County.
Surface altitude: 220 (approximate).
Date: 1945.
Drilled for: Walter Bledsoe & Co.
Logged by: W. E. Berry, Duke University.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Alluvium (Quaternary):						
No core	0		27		27	
Cumnock formation (Triassic):						
Sandstone, gray, fine-grained, noncalcareous	27		29	3	2	3
Shale, gray, soft	29	3	29	7		4
Sandstone, gray, fine-grained, noncalcareous	29	7	31	5	1	10
Shale, gray, soft	31	5	32	11	1	6
Sandstone, fine-grained, noncalcareous, irregularly bedded	32	11	38	4	5	5
Shale, gray to black, calcite parting at 45 ft 9 in. with heavy grease, *Estheria*	38	4	60		21	8
Shale, gray to black, silty, calcite stringers	60		84		24	
Shale, gray-black to gray, calcite partings	84		116	6	32	6
Shale, black, slickensided, *Ostracods*	116	6	119		2	6
Siltstone, gray, calcareous	119		125	6	6	6
Shale, gray, calcareous layers	125	6	128		2	6
Shale, black, non-calcareous	128		134		6	
Shale, gray, silty, variegated	134		141		7	
Shale, gray to black, variegated	141		144		3	
Shale, black nodules, *Ostracods*	144		148	2	4	2
Siltstone and shale, black and gray	148	2	164	6	16	4
Shale, gray, soft, calcareous	164	6	213		48	6
Siltstone, gray	213		214	6	1	6
Shale, gray, soft, calcite partings	214	6	227	8	13	2
Shale, black calcite stringers	227	8	313	3	85	9
Siltstone, gray	313	3	320		6	7
Shale, gray	320		326		6	
Shale, black-bone fragment 328 ft 2 in	326		350		24	
Shale, gray	350		397	2	47	2
Shale, black, calcite layers, slickensided 425 ft 6 in. and 435 ft 6 in., pyrite	397	2	440		42	10
Siltstone, gray, few calcite partings	440		445		5	
Shale, gray and black, pyrite 465 ft	445		498		53	
Shale and coke (?), dark sooty, burnt shale with narrow more or less vertical 1/16 in. layers of coke (May be Cumnock coal metamorphosed by diabase)	498		500	6	2	6
Shale, dark-black, much pyrite and vertical bands 1/16 in. coke	500	6	507	4	6	10
Siltstone, gray, at 498 ft is harsh to touch	507	4	531		23	8
Shale, dark-gray, hard, non-calcareous except partings, much pyrite (measurements unstable from 507 ft 4 in. to 531 ft 9 in.)	531		531	9		9
Diabase fine-grained	531	9	539	7	7	10
Diabase coarse-grained	539	7	578	6	38	11
Bottom of hole	578	6				

[1] In this report, the term "shale, red" probably refers in part to reddish-brown claystone.

DIAMOND-DRILL RECORDS—Continued

Drill hole: BDH 2.
Location: Approximately 11,800 feet S. 71° W. of main shaft of Cumnock mine.
Surface altitude: 249.
Date: 1945.
Drilled for: Walter Bledsoe & Co.
Logged by: W. E. Berry, Duke University.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Surface soil:						
No core	0		26		26	
Sanford formation (Triassic):						
Shale, red	26		29	7	3	7
Siltstone, red, sandy, calcareous	29	7	32		2	5
Shale, red	32		45	7	13	7
Siltstone, red, calcareous nodules	45	7	48		2	5
Siltstone, red, non-calcareous	48		53		5	
Shale, red, few calcite layers	53		66	7	13	7
Sandstone, gray, non-calcareous	66	7	67			5
Sandstone and shale, non-calcareous	67		69	8	2	8
Sandstone, gray, hard, finely arkosic	69	8	70	10	1	2
Sandstone, gray, hard, coarse, few pebbles up to 3/8 in	70	10	80		9	2
Saudstone, gray, hard, calcareous in part	80		90	7	10	7
Sandstone, gray, shaly, non-calcareous	90	7	95		4	5
Sandstone, gray, hard, coarse calcareous nodules and pebbles up to 3/8 in	95		109	5	14	5
Siltstone, gray, and pebbles non-calcareous	109	5	110			7
Siltstone, gray, non-calcareous	110		112	9	2	9
Shale, red	112	9	129	3	16	6
Siltstone, mottled 148 to 149 ft	129	3	181	11	52	8
Shale, red	181	11	187		5	1
Siltstone, red, few calcareous nodules	187		221		34	
Sandstone, gray and red, non-calcareous, top variegated	221		245		24	
Shale, red, some irregular openings in shale	245		259	6	14	6
Siltstone, red limestone nodules up to 1/4 in	259	6	282	3	22	9
Shale, red	282	3	284	5	2	2
Siltstone, red, grading into inclined gray calcareous sandstone at bottom	284	5	308	2	23	9
Shale, gray and red variegated	308	2	313		4	10
Siltstone, reddish-brown	313		316		3	
Sandstone, gray, fine-grained, inclined, some shale lenses slightly calcareous to 4 in	316		332	3	16	3
Shale, gray	332	3	333	4		1
Shale, or siltstone, dark-gray	333	4	337	8	4	4
Siltstone, gray, lumps of red shale	337	8	340	6	2	10
Sandstone, red and gray, slightly calcareous	340	6	352		11	6
Sandstone, gray, calcareous, few flakes of coal at 356 ft 11 in	352		363	5	11	5
Shale, gray to red variegated, soft, occasional siltstone bands, few calcareous sandstone lumps	363	5	406		42	7
Sandstone, gray, fine	406		407	11	1	11
Shale, gray	407	11	408	4		5
Shale, (rotten) red, broken up, soft	408	4	422	1	13	9
Siltstone, red and gray mottled	422	1	437	8	15	7
Siltstone, gray	437	8	438	5		9
Siltstone, red	438	5	439			7
Siltstone, red, occasional red layer	439		450		11	
Siltstone, red, many calcareous nodules, few gray layers	450		459	9	9	9
Shale, mottled red and gray, non-calcareous	459	9	464	9	5	
Siltstone, red, calcareous	464	9	484	4	19	7
Siltstone, gray, non-calcareous	484	4	486		1	8
Shale, red and gray variegated	486		496	6	10	6
Sandstone, red, variegated, calcareous	496	6	507		10	6
Siltstone, red	507		516	10	9	10
Shale, gray	516	10	519	10	3	
Sandstone, variegated red and gray	519	10	520	10	1	
Siltstone, red, calcareous layers	520	10	524	9	3	11
Siltstone, gray	524	9	526	6	1	9
Siltstone, red	526	6	530		3	6
Siltstone, gray, few red nodules	530		554		24	
Siltstone, red and gray mottled	554		556	6	2	6
Siltstone, gray	556	6	561	5	4	11
Shale, gray	561	5	571		9	7
Siltstone, gray, calcareous	571		576	11	5	11

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 2—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Shale, gray, silty	576	11	586	3	9	4
Sandstone, gray, some calcite and pyrite, some limy layers	586	3	630		43	9
Diabase upper contact much broken up; lower contact quite even; coarse in center	630		806	6	176	6
Shale, black (baked hard)	806	6	807	1		7
Sandstone, variegated red and gray, calcareous	807	1	820		12	11
Cumnock formation (Triassic):						
Siltstone, (?) calcite bands on partings	820		834		14	
Sandstone, hard, dense, calcareous, some flecks of carbon—gray black, approximately 500 ft to coal (?)	834		834	8		8
Sandstone, gray, hard, dense, graphitic (?)	834	8	835	6		10
Siltstone, gray, non-calcareous	835	6	851		15	6
Shale, gray, non-calcareous	851		853		2	
Shale, black, soft, many calcite partings, little pyrite	853		898		45	
Shale, gray, calcareous	898		912	3	14	3
Shale, black, calcareous	912	3	915	6	3	3
Shale, gray, calcite partings, sandy and pyrite at 921 ft	915	6	921		5	6
Shale, black, calcareous *Ostracods* 928 ft	921		929		8	
Shale, gray, calcareous	929		933		4	
Shale, black, calcite partings	933		940		7	
Shale, gray, calcareous	940		947		7	
Shale, black	947		952	10	5	10
Shale, dark-gray	952	10	1,005	6	52	8
Shale, black, much broken 1,006 ft. 6 in	1,005	6	1,007	6	2	
Shale, dark-gray to black	1,007	6	1,037	5	29	11
Shale, dark-gray to black, calcite partings	1,037	5	1,172		134	7
(?) hard, dense, slightly calcareous, looks like diabase but lacks cleavages, possibly dense sandstone	1,172		1,175		3	
Shale, black	1,175		1,176		1	
Sandstone or siltstone, looks like diabase	1,176		1,177	6	1	6
Shale, black	1,177	6	1,193	6	16	
Shale, gray, calcareous	1,193	6	1,195		1	6
Shale, black, calcite partings	1,195		1,205		10	
Shale, more or less black	1,205		1,210		5	
Shale, gray, black, calcite partings slickensided 1219 ft. *Fault* 1/4 in. band pyrite 1,220 ft	1,210		1,220		10	
Shale, black, waxy, carbonaceous	1,220		1,220	6		6
Shale, black, carbonaceous	1,220	6	1,229	10	9	4
Shale, black, calcareous nodules	1,229	10	1,234	9	4	11
Shale, black, carbonaceous	1,234	9	1,234	11		2
Shale, black, *Coprolites*	1,234	11	1,236		1	1
Shale, black, carbonaceous	1,236		1,236	4		4
Shale, black	1,236	4	1,237	10½	1	6½
Sandstone, gray, hard	1,237	10½	1,243	4½	5	6
Shale, dark-gray (draw slates)	1,243	4½	1,244	1½		9
Coal (Main bench, Cumnock Coal Bed)	1,244	1½	1,247	9	3	7½
Blackband	1,247	9	1,249	7½	1	10½
Coal (Lower bench, Cumnock Coal Bed)	1,249	7½	1,251		1	4½
Shale, black	1,251		1,251	6		6
Coal (Lower bench, Cumnock Coal Bed)	1,251	6	1,252	3½		9½
Shale, black	1,252	3½	1,254	6	2	2½
Shale, gray, soft	1,254	6	1,258		3	6
Sandstone, gray	1,258		1,259		1	
Shale, gray, soft	1,259		1,261	9½	2	9½
Sandstone, gray, fine-grained	1,261	9½	1,261	10½		1
Shale, gray, soft, calcareous nodules, *Ostracods*	1,261	10½	1,263		1	1½
Coal	1,263		1,263	3		3
Shale, gray, soft (fire clay)	1,263	3	1,264	1½		10½
Sandstone, gray, fine-grained, bedding irregular; few thin non-calcareous shale layers	1,264	1½	1,268	9	4	7½
Shale, black, sandy layers and calcite partings	1,268	9	1,271	4	2	7
Sandstone, gray, fine-grained, non-calcareous	1,271	4	1,273	7	2	3
Shale, black, calcareous partings	1,273	7	1,275	9½	2	2½
Coal (Gulf Coal Bed)	1,275	9½	1,276	6		8½
Shale parting	1,276	6	1,276	7¾		1¾
Coal (Gulf Coal Bed)	1,276	7¾	1,277	11	1	3¼

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 2—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Shale, gray and black	1,277	11	1,278	5½	------	6½
Coal (Gulf Coal Bed)	1,278	5½	1,278	10¼	------	4¾
Shale, gray to black, coaly material and siderite nodules	1,278	10¼	1,279	10¼	1	------
Sandstone, black, hard	1,279	10¼	1,280	------	------	1¾
Shale, black	1,280	------	1,282	6½	2	6½
Sandstone, gray, false-bedded	1,282	6½	1,287	8½	5	2
Shale, black	1,287	8½	1,288	2½	------	6
Sandstone, black	1,288	2½	1,289	2½	1	------
Shale, black	1,289	2½	1,289	11½	------	9
Sandstone, gray, inclined bedding	1,289	11½	1,297	9	7	9½
Coal	1,297	9	1,297	10½	------	1½
Shale, black	1,297	10½	1,298	------	------	1½
Sandstone, gray, grading to fire clay at 1,300 ft	1,298	------	1,300	------	2	------
Bottom of hole	1,300	------	------	------	------	------

[1] In this record the term "shale, red" probably refers in part to reddish-brown claystone.

Drill hole: BDH 3.
Location: Approximately 14,100 feet S. 67° W. of main shaft of Cumnock mine, Chatham County.
Surface altitude: 233.
Date: 1945.
Drilled for: Walter Bledsoe & Co.
Logged by: W. E. Berry, Duke University.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Surface soil:						
No core	0	------	7	------	7	------
Sanford formation (Triassic):						
Sandstone, red, mottled	7	------	9	6	2	6
Shale, red, soft	9	6	10	3	------	9
Sandstone, red, mottled	10	3	10	9	------	6
Shale, red, soft	10	9	16	9	6	------
Sandstone, red, fine-grained	16	9	19	6	2	9
Shale, red	19	6	25	3	5	9
Sandstone, mixed gray and red, fine-grained, non-calcareous	25	3	29	------	3	9
Sandstone, gray, fine- to medium-grained, calcareous	29	------	39	9	10	9
Sandstone, gray, medium- to coarse-grained with few lumps of clay and mica, slightly conglomeratic, non-calcareous	39	9	60	2	20	5
Sandstone, gray, fine-grained	60	2	60	8	------	6
Shale, gray	60	8	60	10	------	2
Shale, red	60	10	64	10	4	------
Shale, red, soft, few gray lumps	64	10	80	------	15	2
Siltstone, red, fine-grained, very few gray lumps	80	------	100	------	20	------
Shale, red, soft	100	------	104	3	4	3
Shale, red, soft, few gray lumps, few silty layers	104	3	144	8	40	5
Siltstone, red	144	8	149	6	4	10
Shale, red, possible worm tracks 153 ft 8 in. few silty layers and clay pebbles	149	6	181	------	31	6
Sandstone, gray, fine-grained	181	------	182	------	1	------
Siltstone, red	182	------	218	6	36	6
Shale, red, crushed and mixed (fault ?)	218	6	220	6	2	------
Siltstone, red, fine-grained	220	6	226	------	5	6
Shale, dark-red, soft	226	------	232	4	6	4
Siltstone, red, fine-grained	232	4	242	4	10	------
Shale, red, soft	242	4	246	6	4	2
Siltstone, red, few shale layers	246	6	250	9	4	3
Shale, red, purple, slightly sandy	250	9	261	6	10	9
Siltstone, purplish-gray, fine-grained	261	6	267	6	6	------
Shale, mottled purplish, red	267	6	268	6	1	------
Siltstone, red, occasional brick-red pebbles up to ⅛ in	268	6	287	2	18	8
Siltstone, mottled red and gray, increasing gray downward	287	2	293	6	6	4
Sandstone, gray, fine- to medium-grained, hard, water-bearing, fine conglomerate layers 309 ft, 315 ft to 318 ft, 325 ft to 328 ft	293	6	332	8	39	2

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 3—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Shale, gray	332	8	335	4	2	8
Shale, dark-purple, red	335	4	337	6	2	2
Siltstone, red	337	6	342	------	4	6
Shale, red, purple	342	------	352	3	10	3
Siltstone, red	352	3	364	------	11	9
Shale, red, soft	364	------	378	10	14	10
Siltstone, red	378	10	383	4	4	6
Shale, red, soft	383	4	385	2	1	10
Siltstone, red shale layer at 390 ft and 395 ft	385	2	400	------	14	10
Siltstone (as above)	400	------	410	------	10	------
Shale, sandy, much broken and slickensided	410	------	412	------	2	------
Siltstone, red- and gray-banded	412	------	416	------	4	------
Siltstone, purple, red	416	------	420	------	4	------
Shale and siltstone with brick-red lumps up to ⅜ in	420	------	420	7	------	7
Shale, purple, red, slightly mottled and silty	420	7	426	------	5	5
Siltstone, purple, red	426	------	434	------	8	------
Shale, purple, red	434	------	434	6	------	6
Siltstone, purple, red, more or less calcareous lumps 441 ft to 442 ft	434	6	442	------	7	6
Shale, purple, red	442	------	445	------	3	------
Siltstone, red	445	------	454	5	9	5
Shale, light-gray with ¼ in. red layers	454	5	455	8	1	3
Shale, dark-purple, red	455	8	458	6	2	10
Siltstone, dark-purple, red	458	6	460	------	1	6
Shale, dark-purple, red	460	------	468	3	8	3
Shale, light-gray, slightly pinkish cast, increasingly darker 475 ft to 478 ft	468	3	478	8	10	5
Shale, gray to purple, red, somewhat silty	478	8	509	7	30	11
Siltstone, purple, red	509	7	514	7	5	------
Shale, purple, red, soft	514	7	517	8	3	1
Shale, gray, red, soft	517	8	519	8	2	------
Shale, gray and red banded, silty	519	8	534	6	14	10
Shale, purplish, dark-gray with narrow red streaks	534	6	539	6	5	0
Siltstone, variegated purple, red, slightly micaceous	539	6	554	6	15	0
Shale, purple, gray	554	6	561	6	7	0
Siltstone, gray with red partings	561	6	562	10	1	4
Shale, purple, gray, sandy 571 ft 8 in., much broken 574 ft 6 in. to 575 ft	562	10	580	0	17	2
Siltstone, purple, red, much broken 581 ft 8 in. to 582 ft 8 in.	580	0	588	8	8	8
Shale, purple, red, hard	588	8	590	4	1	8
Siltstone, purple, red	590	4	594	1	3	9
Shale, purple, red, hard	594	1	606	8	12	7
Siltstone, purple, red, variegated	606	8	609	1	2	5
Siltstone, gray	609	1	609	8	0	7
Siltstone, purple, red	609	8	610	2	0	6
Siltstone, gray	610	2	610	7	0	5
Siltstone, purple, red	610	7	620	9	10	2
Shale, purple, red, hard	620	9	628	5	7	8
Siltstone, purple, red	628	5	631	5	3	0
Sandstone, gray, fine-grained, few red partings	631	5	638	0	6	7
Siltstone, purple, red	638	0	640	8	2	8
Sandstone, gray, very fine-grained	640	8	641	1	0	5
Shale, gray and red variegated	641	1	708	1	67	0
Siltstone, gray, fine-grained	708	1	711	0	2	11
Siltstone, red	711	0	715	10	4	10
Shale, grayish-red	715	10	724	3	8	5
Shale, gray, slightly silty red bands 4 to 16 in. wide, separated by 2 to 4 in. gray bands	724	3	738	0	13	9
Shale, red	738	0	743	0	5	0
Shale, gray	743	0	745	0	2	0
Shale, red mottled	745	0	761	0	16	0
Shale, gray, some red lenses	761	0	772	0	11	0
Shale, gray, slightly pinkish 775 to 776 ft	772	0	776	0	4	0
Shale, purple, red	776	0	776	1	0	1
Shale, gray	776	1	780	6	4	5
Sandstone, gray	780	6	782	6	2	0
Shale, gray, hard	782	6	790	8	8	2
Shale, purplish-gray	790	8	794	9	4	1
Shale, purplish, red, few $CaCO_3$ lumps, slightly silty	794	9	808	8	13	11
Shale, gray, silty	808	8	812	0	3	4
Siltstone, reddish-gray	812	0	816	0	4	0
Cumnock formation (Triassic):						
Siltstone, light gray, few $CaCO_3$ lumps	816	0	845	6	29	6
Siltstone, gray, hard, sort of coletic, noncalcareous	845	6	847	6	2	0

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 3—Continued

Description [1]	Depth from surface: From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
Cumnock formation (Triassic)—Con.						
Shale, gray, soft	847	6	848	0	0	6
Siltstone, gray, hard, slightly coletic	848	0	849	6	1	6
Shale, gray, hard, little pyrite	849	6	853	2	3	8
Siltstone, gray	853	2	855	0	1	10
Shale, gray	855	0	855	6	0	6
Siltstone, fine-grained, dense, much broken, pyrite recovery; quartz	855	6	859	6	4	0
Shale, gray, hard	859	6	860	0	0	6
Shale, black, hard, looks heated or burnt	860	0	861	3	1	3
Siltstone, gray, very hard	861	3	863	4	2	1
Basalt sill; chilled zone about 2 in. wide top and bottom contacts 13° to 15°, smooth	863	4	998	11	135	7
Siltstone, black-burned, fine-grained, hard, some pyrite	998	11	1,003	0	4	1
Shale, black-burned pyrite	1,003	0	1,004	0	1	0
Siltstone, gray, black, hard-burned, siliceous; some nearly vertical quartz stringers healed with calcite	1,004	0	1,012	4	8	4
Sandstone, gray, burned	1,012	4	1,013	10	1	6
Shale, black, some pyrite	1,013	10	1,017	0	3	2
Siltstone, light- to dark-gray, hard	1,017	0	1,018	0	1	0
Shale, gray, hard, silicified	1,018	0	1,032	5	14	5
Sandstone, gray	1,032	5	1,033	4	0	11
Siltstone, gray	1,033	4	1,034	8	1	4
Sandstone, gray	1,034	8	1,039	8	5	0
Shale, gray	1,039	8	1,041	0	1	4
Sandstone, gray, fine-grained	1,041	0	1,043	10	2	10
Shale, dark-gray, hard, pyrite and quartz	1,043	10	1,054	11	11	1
Basalt	1,054	11	1,057	½	2	1½
Shale, black, hard	1,057	½	1,057	6	0	5½
Shale, gray, hard	1,057	6	1,059	6	2	0
Shale, black, hard, *Estheria* 1,060 ft 4 in. to 1,061 ft 8 in	1,059	6	1,063	3	3	9
Shale, gray, hard	1,063	3	1,064	6	1	3
Shale, gray, looks coletic, slightly calcareous; quartz stringer ⅛-in. wide healed with calcite	1,064	6	1,074	6	10	0
Shale, dark-gray to black, hard siliceous	1,074	6	1,079	4	4	10
Shale, black *Ostracods* 1,079 ft 6 in.; *Estheria* 1,081 ft 3 in., 1,084 ft 8 in., 1,087 ft 7 in. 1,105 ft 8 in. to 1,107 ft. *Ostracods* 1,107 ft 6 in	1,079	4	1,108	10	29	6
Shale, dark-gray to black, much pyrite	1,108	10	1,115	4	6	6
Shale, black, *Estheria*, *Ostracods*, and *fish scales* throughout	1,115	4	1,124	10	9	6
Shale, dark-gray, fine-grained, variegated	1,124	10	1,127	0	2	2
Shale, dark-gray, non-bedded	1,127	0	1,127	10	0	10
Shale, black, soft, *Ostracods*, *Estheria*, *Coprolites*, and *fish scales*	1,127	10	1,133	10	6	0
Shale, gray, non-bedded, hard pyrite 1,141 ft 10 in	1,133	10	1,143	0	9	2
Shale, dark-gray, some pyrite	1,143	0	1,146	6	3	6
Shale, black, *Estheria*, *Ostracods* to 1,148 ft 6 in	1,146	6	1,206	0	59	6
Shale, black, *Estheria*, *Ostracods*	1,206	0	1,210	11	4	11
Shale, dark-gray to black, non-bedded	1,210	11	1,225	10	14	11
Shale, black, *Estheria* and *Ostracods*	1,225	10	1,230	0	4	2
Shale, dark-gray, more or less nonbedded	1,230	0	1,244	5	14	5
Shale, black, *Estheria* and *Ostracods*	1,244	5	1,248	0	3	7
Shale, slightly gray, slightly sandy	1,248	0	1,256	0	8	0
Shale, black	1,256	0	1,257	6	1	6
Shale, gray	1,257	6	1,257	8	0	2
Shale, dark-gray, more or less non-bedded	1,257	8	1,262	0	4	4
Shale, black, somewhat disturbed, *Estheria* 1,262 ft 7 in. to 1,262 ft 10¼ in.; sandy layer 1,263 ft 4 in. to 1,263 ft. 5 in	1,262	0	1,263	6	1	6
Shale, black	1,263	6	1,266	0	2	6
Shale, dark-gray, slightly silty	1,266	0	1,280	3	14	3
Shale, black, slightly disturbed	1,280	3	1,281	6	1	3
Shale, black, *Estheria* and *Ostracods*	1,281	6	1,284	5	2	11
Shale, dark-gray to black	1,284	5	1,285	3	0	10
Shale, gray, hard, calcareous	1,285	3	1,296	4	11	1

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 3—Continued

Description [1]	Depth from surface: From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
Cumnock formation (Triassic)—Con.						
Shale, black, *Estheria* 1,297 ft to 1,302 ft 4 in., calcareous 1,302 ft	1,296	4	1,302	4	6	0
Shale, dark-gray to black	1,302	4	1,305	3	2	11
Shale, black	1,305	3	1,316	4	11	1
Shale, black, *Estheria*	1,316	4	1,322	0	5	8
Shale, black, massive at 1,363 ft, *Estheria* and *Ostracods*, some scattered limy layers, rest thin-bedded	1,322	0	1,370	4	48	4
Shale, black, few calcite layers	1,370	4	1,370	10	0	6
Shale, black, crushed for 2 in., then thin-bedded with *Estheria* and few *Ostracods*; some caving around 1,400 ft	1,370	10	1,454	9	83	11
Sandstone, gray, shaly	1,454	9	1,455	9	1	0
Shale, black, thin-bedded	1,455	9	1,457	2	1	5
Sandstone, gray, shaly	1,457	2	1,458	6	1	4
Shale, black, thin-bedded	1,458	6	1,461	0	2	6
Shale, gray, black, irregular bedding more or less slickensided	1,461	0	1,468	0	7	0
Shale, black, thin-bedded, *Estheria* and *Ostracods*, little carbonaceous material; slickensided 1,485 ft to 1,486 ft and 1,487 ft to 1,487 ft 4 in	1,468	0	1,490	2	22	2
Shale, gray, black, sandy	1,490	2	1,491	10	1	8
Shale, black, carbonaceous, many *Coprolites*	1,491	10	1,496	9	4	11
Shale (as above), with many *Ostracods* (poor recovery 10 in. only)	1,496	9	1,497	10	1	1
Shale (as above), 2 in. loss	1,497	10	1,501	2	3	4
Shale, gray, black, disturbed	1,501	2	1,501	5½	0	3½
Coal (Top bench, Cumnock Coal Bed)	1,501	5½	1,501	6½	0	1
Shale, disturbed carbonaceous and plant fragments	1,501	6½	1,502	10¾	1	4¼
Coal (Main bench, Cumnock Coal Bed) pyrite	1,502	10¾	1,506	8	3	9¼
Shale, black	1,506	8	1,507	½	0	4½
Shale, black	1,507	½	1,508	9	1	8½
Coal (Lower bench, Cumnock Coal Bed)	1,508	9	1,508	9½	0	½
Shale, gray	1,508	9½	1,508	10½	0	1
Coal (Lower bench, Cumnock Coal Bed)	1,508	10½	1,510	5	1	6½
Shale, gray	1,510	5	1,510	9¼	0	4¼
Coal (Lower bench, Cumnock Coal Bed)	1,510	9¼	1,511	8¼	0	11
Shale, black, much slickensided at bottom	1,511	8¼	1,512	¼	0	4
Lost, fell out of core barrel	1,512	¼	1,512	4	0	3¾
Bottom of hole	1,512	4				

[1] In this record the term "shale, red" probably refers in part to reddish-brown claystone.

Drill hole BDH 4.
Location: Approximately 10,600 feet S. 76° W. of main shaft of Cumnock mine. Chatham County.
Surface altitude: 228.
Date: 1945.
Drilled for: Walter Bledsoe & Co.
Logged by: W. E. Berry, Duke University.

Description [1]	Depth from surface: From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
Surface soil:						
No core	0	0	22	0	22	0
Sanford formation (Triassic):						
Sandstone, grayish-brown, fine-grained	22	0	23	0	1	0
Sandstone, coarse-grained, porous, water-bearing	23	0	28	0	5	0
Sandstone, grayish-brown, reddish, fine-grained, 31 ft-32 ft	28	0	32	0	4	0
Sandstone, gray, fine-grained	32	0	41	0	9	0
Sandstone, gray, medium-grained, some angular grains, vertical fractures	41	0	43	6	2	6
Shale, gray, sandy	43	6	44	0	0	6

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Sandstone, gray, fine- to coarse-grained, angular grains and shale fragments, vertical fractures	44	0	48	0	4	0
Shale, gray, sandy	48	0	48	4	0	4
Sandstone, gray, fine-grained, soft	48	4	49	4	1	0
Shale, gray, sandy, reddish-purple nodules	49	4	54	0	4	8
Shale, mottled red and gray	54	0	64	6	10	6
Shale, reddish, sandy	64	6	68	6	4	0
Shale, red, some brownish-gray layers, slightly sandy, more or less pebbly layer 124 ft. and 125 ft; some brick-red lumps ⅛ in.–¼ in. diameter; gray layer 155 ft 1 in. to 155 ft 2 in.	68	6	181	2	112	8
Sandstone, red, fine-grained, hard	181	2	186	5	5	3
Sandstone, gray, fine-grained	186	5	193	0	6	7
Shale, gray, non-bedded	193	0	194	2	1	2
Sandstone, gray, fine- to coarse-grained	194	2	195	8	1	6
Shale, red, soft	195	8	211	6	15	10
Shale, red, sandy, many clay pellets 223 ft–244 ft	211	6	224	0	12	6
Shale, red, soft	224	0	228	0	4	0
Shale, red, sandy	228	0	228	4	0	4
Shale, red, somewhat variegated, inclined to be slightly sandy	228	4	255	11	27	7
Sandstone, gray, fine to medium-grained arkosic	255	11	269	0	13	1
Sandstone, gray, fine-grained	269	0	269	11	0	11
Sandstone, gray, medium-grained, arkosic	269	11	277	4	7	5
Sandstone, gray, fine-grained	277	4	278	6	1	2
Sandstone, gray, medium-grained, arkosic	278	6	280	0	1	6
Sandstone, gray, fine-grained	280	0	283	10	3	10
Shale, red, slightly sandy	283	10	284	1	0	3
Sandstone, gray, fine-grained	284	1	291	7	7	6
Shale, red	291	7	296	0	4	5
Sandstone, red, fine-grained, shaly	296	0	297	0	1	0
Shale, red, sandy	297	0	297	8	0	8
Sandstone, red and gray, fine-grained	297	8	309	2	11	6
Shale, red, soft	309	2	314	2	5	0
Shale, red, sandy	314	2	323	4	9	2
Shale, red, soft	323	4	324	0	0	8
Shale, red, sandy	324	0	327	6	3	6
Shale, grayish-red, sandy	327	6	330	0	2	6
Sandstone, gray, fine-grained, red-mottled	330	0	343	2	13	2
Shale, red, soft	343	2	344	3	1	1
Sandstone, gray, fine-grained	344	3	345	0	0	9
Shale, gray, soft	345	0	347	0	2	0
Shale, red, sandy	347	0	363	0	16	0
Shale, red	363	0	370	0	7	0
Shale, red, sandy	370	0	375	0	5	0
Shale, red, mottled	375	0	382	11	7	11
Shale, red, soft	382	11	391	2	8	3
Shale, red, sandy, less sandy 400 ft	391	2	402	0	10	10
Shale, red, soft	402	0	404	0	2	0
Shale, red, quite sandy	404	0	415	6	11	6
Shale, red, scattered calcite nodules to ½ in diameter	415	6	421	6	6	0
Shale, red, sandy (siltstone)	421	6	434	9	13	3
Shale, red, soft	434	9	438	6	3	9
Shale, red, sandy (siltstone) mottled 440 ft–442 ft	438	6	442	9	4	3
Shale, red, soft	442	9	451	1	8	4
Shale, red, sandy (siltstone)	451	1	454	4	3	3
Shale, red, soft	454	4	455	2	0	10
Siltstone, red and gray	455	2	455	6	0	4
Siltstone, to very fine-grained sandstone	455	6	460	0	4	6
Siltstone, reddish and mottled with gray	460	0	489	0	29	0
Shale, red, soft	489	0	497	0	8	0
Siltstone, red and gray	497	0	522	2	25	2
Cumnock formation (Triassic):						
Shale, gray with slight reddish tone	522	2	547	0	24	10
Shale, black, *plant* fragments	547	0	553	3	6	3
Shale, gray, black, sandy	553	3	555	7	2	4
Shale, light-gray, black	555	7	557	2	1	7
Shale, black	557	2	562	0	4	10
Sandstone, gray, hard	562	0	563	4	1	4
Basalt (?), very hard fine-grained	563	4	565	0	1	8
Shale, gray	565	0	565	9	0	9
Shale, black, very much slickensided and caved (mostly lost)	565	9	568	2	2	5
Shale, gray, hard, slickensided	568	2	570	0	1	10

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 4—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Shale, gray to black, slickensided. (1 ft lost)	570	0	574	0	4	0
Shale, gray to black, loss 3 in	574	0	576	3	2	3
Shale, reddish	576	3	576	4	0	1
Basalt	576	4	578	1	1	9
Shale, gray	578	1	578	8	0	7
Sandstone, gray	578	8	579	9	1	1
Shale, gray	579	9	583	10	4	1
Sandstone, gray, shaly layers	583	10	585	4	1	6
Shale, gray	585	4	587	11	2	7
Sandstone, gray	587	11	588	11	1	0
Shale, dark-gray, sandy, badly slickensided 590 ft 6 in	588	11	590	6	1	7
Shale, black *Ostracods* and *Estheria* much slickensided	590	6	596	7	6	1
Sandstone, gray	596	7	597	4	0	9
Shale, black, slickensided	597	4	598	5	1	1
Shale, black	598	5	600	4	1	11
Loss of 2-ft core between 587 ft 11 in. and 600 ft 4 in., probably at 596 ft 7 in. and 598 ft 5 in.						
Shale, black	600	4	600	11	0	7
Sandstone or basalt, oil in openings	600	11	602	10	1	11
Shale, black, some calcite layers, badly slickensided, some loss	602	10	610	2	7	4
Shale, gray, lower 2 in. burnt and dark, few round end *Ostracods*	610	2	629	10	19	8
Basalt	629	10	631	3	1	5
Shale, dark-gray, non-bedded	631	3	636	8	5	5
Basalt	636	8	637	11	1	3
Shale, gray, non-bedded	637	11	649	6	11	7
Basalt, top contact horizontal, bottom contact dips 60°	649	6	651	3	1	9
Shale, dark-gray	651	3	654	2	2	11
Basalt	654	2	655	0	0	10
Shale, black	655	0	656	5	1	5
Shale, black, much caving, only 4 in. recovery	656	5	657	2	0	9
Shale, black, soft, thin-bedded *Estheria* and *Ostracods*	657	2	658	10	1	8
Shale, gray	658	10	666	0	7	2
Shale, black, calcite veins, *Ostracods* broken, slickensided 671 ft	666	0	672	3	6	3
Shale, gray	672	3	677	8	5	5
Shale, black *Ostracods*	677	8	678	10	1	2
Shale, black, calcite stringers, few *Coprolites*, *Ostracods*, fish scales	678	10	682	6	3	8
Siltstone, gray, oil 682 ft to 682 ft 8 in	682	6	690	0	7	6
Shale, dark-gray, calcite stringers	690	0	694	0	4	0
Shale, black, calcite stringers	694	0	696	0	2	0
Shale, dark-gray to gray, hard, disturbed 731 ft 6 in. to 731 ft 9 in	696	0	753	9	57	9
Shale, black, thin-bedded, calcite stringers	753	9	758	9	5	0
Shale, gray	758	9	769	8	10	11
Shale, dark-gray to black	769	8	770	0	0	4
Shale, dark-gray, calcite stringers	707	0	771	3	1	3
Shale, gray	771	3	775	0	3	9
Shale, black, thin-bedded	775	0	780	0	5	0
Shale, gray	780	0	787	4	7	4
Shale, dark-gray	787	4	793	4	6	0
Shale, black	793	4	796	6	3	2
Shale, gray, few scattered calcite stringers	796	6	814	0	17	6
Shale, dark-gray, calcite stringers	814	0	817	0	3	0
Shale, gray	817	0	833	5	16	5
Shale, black, calcite stringers	833	5	836	8	3	3
Shale, dark-gray to gray	836	8	854	6	17	10
Shale, gray	854	6	862	5	7	11
Basalt	862	5	862	8	0	3
Shale, gray to dark-gray	862	8	870	0	7	4
Shale, black, thin-bedded	870	0	875	0	5	0
Shale, gray	875	0	888	0	13	0
Shale, black	888	0	896	0	8	0
Shale, dark-gray and black, few calcite stringers, sandy 905 ft 6 in. to 905 ft 9 in., few 2–3 in. sills and a few 1 in. sandy layers	896	0	920	0	24	0
Shale, black, much broken 924 ft 11 in	920	0	931	8	11	8
No core (lost)	931	8	933	4	1	8
Shale, black, *Coprolites*, very badly broken up about 941 to 942 ft	933	4	943	0	9	8
Sandstone, slickensided and shaly	943	0	943	7	0	7

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 4—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Shale, black, broken and slickensided	943	7	944	8	1	1
Sandstone, gray, little gray shale	944	8	947	3	2	7
Shale, black	947	3	947	5½	0	2½
Coal and shale at main seam or upper bench ends. About 43 in. of coal (Main bench, Cumnock Coal Bed)	947	5½	952	0	4	6½
Shale, blackband	952	0	953	7	1	7
Coal (Lower bench, Cumnock Coal Bed)	953	7	955	2	1	7
Shale, black	955	2	955	8	0	6
Coal (Lower bench, Cumnock Coal Bed)	955	8	956	5½	0	9½
Shale, black	956	5½	958	0	1	6½
Sandstone, gray, false-bedded, shaly	958	0	960	0	2	0
Shale, gray, black slickensided	960	0	963	10	3	10
Coal	963	10	964	3	0	5
Shale, gray	964	3	964	8	0	5
Sandstone, false-bedded, oily	964	8	974	6	9	10
Shale, black, sandy, *Coprolites* (blackband)	974	6	975	0	0	6
Shale, black, slickensided	975	0	977	6	2	6
Coal (Gulf Coal Bed)	977	6	977	9	0	3
Coal (Gulf Coal Bed) boney	977	9	978	5	0	8
Coal (Gulf Coal Bed)	978	5	979	10	1	5
Shale, dark-gray	979	10	980	4	0	6
Coal (Gulf Coal Bed)	980	4	980	8	0	4
Shale, black	980	8	983	0	2	4
Bottom of hole	983	0	-------	-------	-------	-------

[1] In this record the term "shale, red" probably refers in part to reddish-brown claystone.

Drill hole BDH 5.

Location: Approximately 10,600 feet S. 78° W. of main shaft of Cumnock mine, Chatham County.

Surface altitude: 227.

Date: 1945.

Drilled for: Walter Bledsoe & Co.

Logged by: W. E. Berry, Duke University.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Surface soil:						
No core	0	0	15	0	15	0
Sanford formation (Triassic):						
Shale, red, soft (some core lost)	15	0	20	3	5	3
Shale, gray, soft	20	3	31	0	10	9
Siltstone, brown	31	0	35	0	4	0
Siltstone, gray	35	0	37	0	2	0
Sandstone, fine- to medium-grained	37	0	46	0	9	0
Sandstone, red and gray mottled, medium- to slightly coarse-grained	46	0	48	0	2	0
Sandstone, gray, medium- to coarse-grained, some pebbles up to ½-in., arkosic	48	0	58	11	10	11
Siltstone, red and gray variegated	58	11	63	5	4	6
Sandstone, gray, fine- to medium-grained	63	5	67	2	3	9
Shale, gray, soft	67	2	67	4	0	2
Sandstone, dark-gray, arkosic, medium-soft, some shale (gray) lumps	67	4	84	7	17	3
Shale, gray, soft	84	7	84	8	0	1
Sandstone, gray, fine- to medium-grained	84	8	93	0	8	4
Sandstone, fine-grained, gray shale flakes	93	0	95	0	2	0
Sandstone, gray, fine- to medium-grained, few flakes black shale 96 ft 5 in	95	0	97	0	2	0

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 5—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Shale, gray, soft, slickensided 99 ft 7 in. at about 60°; color change to next on slickenside. (Small fault)	97	0	99	7	2	7
Shale, gray, reddish or brownish	99	7	105	4	5	9
Shale, brownish, soft	105	4	106	8	1	4
Sandstone, gray, medium-grained	106	8	107	7	0	11
Shale, gray, soft	107	7	108	11	1	4
Sandstone, gray, medium-grained	108	11	109	7	0	8
Shale, gray, soft, broken	109	7	110	1	0	6
Sandstone, gray, medium-grained	110	1	110	6	0	5
Shale, red, soft, some gray mottling	110	6	113	4	2	10
Siltstone, red, some gray lumps and streaks	113	4	125	6	12	2
Shale, red, silty	125	6	134	11	9	
Shale, red, soft, mottled	134	11	141	6	6	7
Siltstone, red	141	6	146	3	4	9
Sandstone, red, gray, fine-grained, false-bedded spotted and arkosic up to ¼ in	146	3	153	0	6	9
Sandstone, gray and red, fine-grained	153	0	154	0	1	0
Sandstone, gray, fine-grained	154	0	155	7	1	7
Sandstone, red, fine-grained	155	7	156	0	0	5
Sandstone, gray, fine-grained, false-bedded, some red	156	0	161	8	5	8
Siltstone, red	161	8	165	0	3	4
Shale, red, sandstone pellets up to ¼ in	165	0	165	10	0	10
Siltstone, red	165	10	171	0	5	2
Shale, red, hard, slickensided 171 ft 6 in. 60° angle	171	0	179	8	8	8
Siltstone, red, hard, vertical fracture 185 ft	179	8	187	6	7	10
Shale, red, soft	187	6	193	6	6	0
Siltstone, red	193	6	195	0	1	6
Shale, red, soft, slickensided 260 ft 6 in	195	0	213	0	18	0
Siltstone, red	213	0	226	0	13	0
Shale, mottled red and gray, much broken	226	0	228	0	2	0
Shale, gray with red	228	0	232	6	4	6
Shale, light-red	232	6	249	0	16	6
Siltstone, red	249	0	255	4	6	4
Sandstone, gray, fine-grained, false-bedded	255	4	261	0	5	8
Sandstone, reddish-gray, medium-grained	261	0	261	8	0	8
Siltstone, red	261	8	265	8	4	0
Shale, red, silty	265	8	268	6	2	10
Siltstone, gray, slickensided 272 ft	268	6	275	0	6	6
Sandstone, gray, fine- to medium-grained	275	0	281	8	6	8
Shale, gray, few red layers	281	8	288	0	6	4
Siltstone, gray	288	0	288	3	0	3
Shale, gray, badly slickensided	288	3	288	6	0	3
Sandstone, "pepper and salt" medium-grained	288	6	291	5	2	11
Siltstone, dark-gray	291	5	297	0	5	7
Siltstone, dark-gray	297	0	302	0	5	0
Shale, gray, several 60° slickensided surfaces	302	0	304	4	2	4
Shale, reddish-gray, heavy 60°, slickensided surfaces	304	4	305	0	0	8
Siltstone, red and gray variegated but mostly gray, false-bedded	305	0	310	4	5	4
Cumnock formation (Triassic):						
Shale, gray, sandy, hard	310	4	314	8	4	4
Fault breccia—coal, basalt, gray shale, dark-gray shale, angular and mixed up [2]	314	8	592	6	277	10
Fault breccia. 617 ft 0 in. to 617 ft 10 in. contains *coal*	592	6	651	0	58	6
Shale, black *Coprolites*	651	0	652	0	1	0
Pekin formation (?) (Triassic):						
Shale, reddish	652	0	654	0	2	0
Shale, red	654	0	656	4	2	4
Shale, red and gray	656	4	668	0	11	8
Shale, red and gray	668	0	737	0	69	0
Bottom of hole	737	0	-------	-------	-------	-------

[1] In this record the term "shale, red" probably refers in part to reddish-brown claystone.

[2] Probably Gulf fault breccia. This hole started in the Sanford formation on the downthrown side of the Gulf fault and probably finished in the Pekin formation on the upthrown side. Most of the Cumnock formation and the coal beds have been cut out by this fault, but fragments of Cumnock strata are included in the fault breccia.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 6.
Location: Approximately 24,900 feet S. 65° W. of main shaft of Cumnock mine, Lee County.
Surface altitude: 275 (approximate).
Date: 1945.
Drilled for: Walter Bledsoe & Co.
Logged by: W. E. Berry, Duke University.

Description 1	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Terrace gravel deposits (Quaternary):						
No core	0	0	23	0	23	0
Sanford formation (Triassic):						
Shale, red, soft and weathered	23	0	38	4	15	4
Siltstone, red	38	4	44	4	6	0
Siltstone, red	44	4	53	8	9	4
Shale, red, soft, worm tracks	53	8	68	0	14	4
Siltstone, red	68	0	83	8	15	8
Shale, red, soft	83	8	91	2	7	6
Siltstone, red	91	2	95	4	4	2
Shale, red, increasing darker downward, worm tracks	95	4	100	0	4	8
Shale, dark purplish-red, few mud lumps	100	0	104	5	4	5
Siltstone, variegated, red and gray	104	5	108	3	3	10
Sandstone, gray and red, fine-grained, micaceous	108	3	109	3	1	0
Shale, red, soft, slightly silty	109	3	111	0	1	9
Siltstone, gray and red	111	0	113	5	2	5
Shale, red	113	5	114	6	1	1
Siltstone, reddish-gray	114	6	116	10	2	4
Siltstone, red, conglomerate at base	116	10	120	6	3	8
Shale, red, few mud lumps	120	6	130	0	9	6
Siltstone, dark purplish-red	130	0	135	0	5	0
Shale, dark-purple, red	135	0	140	2	5	2
Sandstone, dark-purple, red. Cross-bedded at 153 ft 3 in	140	2	154	7	14	5
Shale, red, soft	154	7	169	5	14	10
Sandstone, gray, fine-grained	169	5	170	0	0	7
Shale, red and gray mottled	170	0	170	5	0	5
Sandstone, gray, fine-grained	170	5	172	0	1	7
Sandstone, gray, fine- to medium-grained, arkosic	172	0	179	2	7	2
Sandstone, gray, medium-grained, slightly arkosic	179	2	182	0	2	10
Shale, red, soft	182	0	186	0	4	0
Siltstone, red, some cross-bedding	186	0	198	0	12	0
Shale, red and gray mottled	198	0	203	2	5	2
Siltstone, red	203	2	206	10	3	8
Shale, red, soft, crushed	206	10	207	6	0	8
Shale, grayish-pink, 1/16 in. red spots	207	6	211	0	3	6
Shale, mottled red and gray	211	0	211	6	0	6
Siltstone, mottled red and gray	211	6	217	3	5	9
Shale, red	217	3	220	0	2	9
Siltstone, mottled red and gray	220	0	227	6	7	6
Shale, gray, hard	227	6	231	8	4	2
Siltstone, red, pinkish 236 ft	231	8	242	11	11	3
Shale, red	242	11	244	0	1	1
Siltstone, red	244	0	248	9	4	9
Shale, dark grayish-red	248	9	252	3	3	6
Sandstone, red	252	3	255	8	3	5
Shale, red	255	8	257	0	1	4
Siltstone, red	257	0	260	8	3	8
Shale, red, soft	260	8	261	7	0	11
Siltstone, red, few gray layers	261	7	273	0	11	5
Shale, red, soft, caving 277 ft	273	0	279	11	6	11
Siltstone, red	279	11	281	9	1	10
Sandstone, few red layers as much as 1 in. thick, fine-to medium-grained	281	9	297	0	15	3
Shale, red, soft	297	0	309	0	12	0
Siltstone, red	309	0	316	4	7	4
Shale, red	316	4	321	0	4	8
Siltstone, red, spotted 326 ft–327 ft	321	0	335	4	14	4
Shale, red	335	4	339	8	4	4
Siltstone, red	339	8	341	10	2	2
Siltstone, mottled red and gray	341	10	342	9	0	11
Siltstone, red	342	9	345	0	2	3
Sandstone, gray	345	0	345	9	0	9
Shale, mottled red and gray	345	9	351	0	5	3
Shale, gray, sandy	351	0	352	4	1	4
Shale, black	352	4	352	6	0	2
Shale, gray, sandy	352	6	355	0	2	6
Shale, mottled red and gray	355	0	356	4	1	4
Siltstone, red	356	4	368	6	12	2
Siltstone, mottled red and gray	368	6	374	5	5	11
Shale, red, soft, some gray spots	374	5	384	6	10	1
Shale, gray, some red lumps	384	6	386	6	2	0
Sandstone, gray, fine-grained	386	6	388	8	2	2
Shale, gray	388	8	389	10	1	2
Shale, red, soft	389	10	393	0	3	2
Siltstone, gray, hard	393	0	396	3	3	3
Shale, purplish, red	396	3	416	5	20	2
Siltstone, gray	416	5	417	2	0	9
Sandstone, gray, fine-grained	417	2	418	5	1	3

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 6—Continued

Description 1	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Shale, gray	418	5	419	2	0	9
Shale, purplish, red	419	2	424	5	5	3
Siltstone, reddish-brown	424	5	425	0	0	7
Shale, red, soft, few calcareous nodules	425	0	433	7	8	7
Sandstone, gray, fine-grained	433	7	443	0	9	5
Shale, gray, sandy	443	0	444	0	1	0
Shale, mottled red and gray (lost 2 ft 8 in.)	444	0	451	7	7	7
Shale, dark purplish-red	451	7	453	8	2	1
Sandstone, gray, fine-to medium-grained	453	8	455	3	1	7
Shale, dark purplish-gray	455	3	462	6	7	3
Sandstone, gray, fine-to medium-grained, micaceous	462	6	467	3	4	9
Shale, gray, soft	467	3	468	10	1	7
Shale, gray, and dark purplish-gray, soft	468	10	476	1	7	3
Cumnock formation (Triassic):						
Sandstone, light-gray, fine-grained	476	1	482	9	6	8
Shale, light-gray, sandy	482	9	483	0	0	3
Sandstone, light-gray, fine-grained	483	0	488	7	5	7
Shale, light-gray	488	7	488	9	0	2
Sandstone, light-gray, fine-grained	488	9	489	0	0	3
Shale, light-gray	489	0	489	3	0	3
Sandstone, light-gray, fine-grained	489	3	489	5	0	2
Shale, light-gray	489	5	489	7	0	2
Sandstone, light-gray, fine-grained	489	7	490	7	1	0
Shale, light-gray, soft	490	7	491	4	0	9
Sandstone, light-gray, fine-grained	491	4	493	5	2	1
Shale, gray, soft	493	5	493	10	0	5
Sandstone, light-gray, fine-grained some almost-white spots	493	10	501	4	7	6
Shale, gray, hard and somewhat crushed	501	4	509	9	8	5
Shale, black	509	9	512	6	2	9
Sandstone, gray, fine-grained	512	6	514	7	2	1
Shale, black	514	7	517	9	3	2
Sandstone, gray with 1/10 in. shaly layers	517	9	519	6	1	9
Shale, black *Coprolites*	519	6	521	8	2	2
Sandstone, gray, fine-grained	521	8	522	9	1	1
Shale, black	522	9	523	8	0	11
Sandstone, gray, fine-grained	523	8	525	4	1	8
Shale, gray to black	525	4	526	1	0	9
Sandstone, gray, fine-grained	526	1	530	0	3	11
Shale, black	530	0	535	4	5	4
Shale, dark-gray	535	4	538	0	2	8
Shale, black	538	0	539	0	1	0
Shale, dark-gray	539	0	540	8	1	8
Shale, black	540	8	541	5	0	9
Shale, dark-gray	541	5	545	3	3	10
Sandstone, gray, fine-grained	545	3	546	8	1	5
Shale, dark-gray	546	8	550	5	3	9
Shale, dark-gray to black	550	5	554	4	3	11
Sandstone, gray, fine-grained	554	4	559	3	4	11
Shale, gray	559	3	559	8	0	5
Sandstone, gray, fine-grained, some shale layers	559	8	562	11	3	3
Sandstone, gray, fine- to medium-grained, few carbon flecks	562	11	564	0	1	1
Shale and sandstone, gray, alternate layers	564	0	565	5	1	5
Sandstone, gray, fine- to medium-grained	565	5	565	10	0	5
Shale, dark-gray, silty	565	10	571	2	5	4
Shale, black	571	2	590	0	18	10
Shale, gray, hard, calcite partings	590	0	612	5	22	5
Shale, black	612	5	624	8	12	3
Shale, black	624	8	629	3	4	7
Shale, gray, hard, calcite stringers	629	3	642	3	13	0
Shale, dark-gray, calcite stringers	642	3	646	8	4	5
Shale, black, few calcite stringers	646	8	650	9	4	1
Shale, gray, hard, crushed	650	9	656	11	6	2
Shale, black calcite stringers, *coprolites*	656	11	663	3	6	4
Shale, gray	663	3	667	0	3	9
Shale, black, *coprolites*	667	0	667	4	0	4
Shale, gray, calcite 667 ft 6 in	667	4	671	10	4	6
Shale, black, few 1/4 in. to 1/2 in. *coprolites*, gray layers, broken and crushed 675 ft to 676 ft 6 in. Odor oil 673 ft to 675 ft	671	10	676	9	4	11
Shale, gray, hard	676	9	688	4	11	7

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 6—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Shale, dark-gray, slightly brownish	688	4	691	10	3	6
Shale, black, calcite layers	691	10	694	11	3	1
Shale, dark-gray and gray, occasional ½ in. sandy layers	694	11	699	0	4	1
Shale, gray, hard, calcite stringers	699	0	710	0	11	0
Shale, dark-gray, hard calcite stringers	710	0	715	1	5	1
Shale, gray, hard, calcite stringers	715	1	729	7	14	6
Shale, gray, occasional sandy layer up to ½ in. Little pyrite 753 ft to 761 ft	729	7	761	10	32	3
Shale, black. *Ostracods*	761	10	770	6	8	8
Shale, dark-gray	770	6	773	8	3	2
Sandstone, light-gray, fine-grained, calcareous, hard	773	8	774	2	0	6
Shale, dark-gray	774	2	775	0	0	10
Sandstone, light-gray, fine-grained, calcareous, hard	775	0	775	4	0	4
Shale, dark-gray	775	4	775	11	0	7
Sandstone, gray, fine-grained, calcareous	775	11	776	2	0	3
Shale, black, more or less broken to 802 ft 3 in.—*Estheria*, *Ostracods*, *Coprolites*, burnt 796 ft downward	776	2	822	0	45	10
Shale, dark-gray	822	0	825	0	3	0
Shale, black	825	0	826	0	1	0
Shale, gray	826	0	839	5	13	5
Shale, black, *Estheria*, *Ostracods*, *Coprolites*	839	5	842	6	3	1
Shale, gray	842	6	845	7	3	1
Shale, black	845	7	849	9½	4	2½
Basalt or diabase, much broken, in places. Open vertical crack 863 ft to 864 ft, partly open 70° fissure 938 ft to 938 ft 8 in	849	9½	994	6	144	8½
Shale, black, burnt, many *Coprolites*, pyrite 1,005 ft to 1,010 ft	994	6	1,010	4	15	10
Coal (Top bench Cumnock Coal Bed), anthracite	1,010	4	1,010	4⅝	0	⅝
Shale, black	1,010	4⅝	1,010	5⅛	0	½
Coal (Top bench Cumnock Coal Bed), anthracite	1,010	5⅛	1,010	8⅞	------	3¾
Shale, black	1,010	8⅞	1,010	10⅝	------	1¾
Coal (Top bench Cumnock Coal Bed), anthracite	1,010	10⅝	1,011	11⅛	1	½
Shale, black	1,011	11⅛	1,012	10⅝	0	11½
Coal (Main bench, Cumnock Coal Bed), anthracite	1,012	10⅝	1,015	9⅛	2	10½
Shale, black	1,015	9⅛	1,017	7⅛	1	10
Coal (Lower bench, Cumnock Coal Bed), anthracite	1,017	7⅛	1,018	8⅛	1	1
Shale, black, pyrite 1,020 ft 11 in	1,018	8⅛	1,021	0	2	3⅞
Shale, gray	1,021	0	1,035	0	14	0
Shale, black	1,035	0	1,037	0	2	0
Sandstone, gray, fine-grained	1,037	0	1,038	0	1	0
Shale, black	1,038	0	1,038	5	0	5
Coal, anthracite	1,038	5	1,038	7	0	2
Shale, black to gray	1,038	7	1,042	6	3	11
Coal, anthracite	1,042	6	1,042	8	0	2
Shale, black	1,042	8	1,043	0	0	4
Shale, gray, sandy, 1,046 ft slickensided	1,043	0	1,046	0	3	0
Shale, gray	1,046	0	1,047	11	1	11
Coal (Gulf Coal Bed)	1,047	11	1,048	11	1	0
Shale, black, sandy, 6 in. lost out of core barrel	1,048	11	1,054	0	5	1
Bottom of hole	1,054	0	------	------	------	------

[1] In this record the term "shale, red" probably refers in part to reddish-brown claystone.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 7.
Location: Approximately 24,700 feet S. 61° W. of main shaft of Cumnock mine, Lee County.
Surface altitude: 270 (approximate).
Date: 1945.
Drilled for: Walter Bledsoe & Co.
Logged by: W. E. Berry, Duke University.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Surface soil:						
No core	0	0	27	0	27	0
Sanford formation (Triassic):						
Shale, red, variegated	27	0	56	0	29	0
Shale, grayish, red	56	0	57	6	1	6
Sandstone, gray, medium-grained, arkosic	57	6	72	0	14	6
Shale, gray	72	0	73	0	1	0
Shale, red	73	0	81	0	8	0
Siltstone, red	81	0	86	0	5	0
Shale, red, soft, slightly mottled	86	0	112	0	26	0
Siltstone, gray, shaly, red 134 ft	112	0	137	0	25	0
Shale, red, soft	137	0	146	9	9	9
Siltstone, red	146	9	150	9	4	0
Shale, red, soft	150	9	152	0	1	3
Siltstone, red	152	0	154	0	2	0
Shale, red, soft	154	0	160	0	6	0
Siltstone, red, mottled, few brick-red lumps	160	0	169	6	9	6
Shale, red	169	6	186	0	16	6
Siltstone, red	186	0	188	2	2	2
Shale, red, soft	188	2	205	10	17	8
Siltstone, red	205	10	207	8	1	10
Shale, red, soft. (Opening 211 ft 3 in. to 211 ft 11 in.—sort of open crack). About 4 ft of core lost	207	8	220	0	12	4
Siltstone, reddish-gray	220	0	224	0	4	0
Sandstone, gray, fiine-grained	224	0	227	0	3	0
Sandstone, gray, and reddish, fine-grained	227	0	230	0	3	0
Siltstone, red	230	0	232	0	2	0
Shale, red, mottled	232	0	234	2	2	2
Shale, red, and gray variegated	234	2	237	8	3	6
Shale, red, sandy 251 ft	237	8	259	9	22	1
Siltstone, or fine-grained sandstone, red	259	9	272	6	12	9
Siltstone, red	272	6	277	0	4	6
Shale, red	277	0	279	6	2	6
Siltstone, red, variegated shale parting 1 ft at 28 ft 7 in	279	6	292	0	12	6
Shale, red, soft	292	0	295	10	3	10
Siltstone, red	295	10	304	8	8	10
Shale, red	304	8	308	0	3	4
Siltstone, red	308	0	314	3	6	3
Shale, red, variegated 324 to 327 ft	314	3	334	6	20	3
Sandstone, gray, fine-grained	334	6	335	6	1	0
Shale, red, variegated	335	6	348	8	13	2
Sandstone, red and gray, fine-grained	348	8	353	1	4	5
Shale, red, soft	353	1	357	0	3	11
Siltstone, red	357	0	368	0	11	0
Siltstone, gray	368	0	369	0	1	0
Shale, red	369	0	413	2	44	2
Sandstone, gray, fine-grained, scattered red layers	413	2	417	0	3	10
Siltstone, red	417	0	423	0	6	0
Sandstone, gray, fine-grained, few red spots	423	0	427	0	4	0
Siltstone, red	427	0	431	6	4	6
Sandstone, gray, fine-grained	431	6	438	0	6	6
Shale, dark-gray to black, slickensided	438	0	438	9	0	9
Sandstone, gray, fine-grained	438	9	442	3	3	6
Shale, red	442	3	443	5	1	2
Sandstone, gray, fine-grained, occasional red spots	443	5	452	0	8	7

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 7—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Siltstone, red	452	0	458	0	6	0
Shale, red, soft	458	0	460	0	2	0
Siltstone, red	460	0	461	0	1	0
Sandstone, gray, fine- to medium-grained	461	0	467	0	6	0
Siltstone, red	467	0	482	0	15	0
Sandstone, gray, fine-grained	482	0	487	0	5	0
Shale, gray, soft	487	0	489	2	2	2
Siltstone, red	489	2	491	3	2	1
Siltstone, gray, some red layers	491	3	502	0	10	9
Siltstone, gray, mottled, red	502	0	512	0	10	0
Siltstone, mottled red and gray	512	0	526	0	14	0
Cumnock formation (Triassic):						
Sandstone, gray, very fine-grained	526	0	540	0	14	0
Shale, gray, hard	540	0	542	0	2	0
Siltstone, gray	542	0	549	10	7	10
Shale, black, calcite stringers	549	10	549	11	0	1
Shale, gray	549	11	550	4	0	5
Shale, black	550	4	552	0	1	8
Shale, gray	552	0	553	6	1	6
Sandstone, gray, fine-grained	553	6	560	0	6	6
Shale, black	560	0	564	0	4	0
Sandstone, gray	564	0	566	0	2	0
Shale, black	566	0	567	0	1	0
Sandstone, gray, crossbedded in places	567	0	570	3	3	3
Shale, black, few *coprolites*	570	3	579	9½	9	6½
Coal	579	9½	580	0	0	2½
Shale, black	580	0	580	4	0	4
Shale, black	580	4	585	0	4	8
Sandstone, gray, fine-grained	585	0	587	0	2	0
Shale, gray	587	0	592	0	5	0
Not examined	592	0	830	0	238	0
Diabase	830	0	944	0	114	0
Shale, pinkish-gray, burnt	944	0	946	2	2	2
Shale, gray and whitish, burnt hard	946	2	966	0	19	10
Shale, gray	966	0	972	0	6	0
Shale, dark-gray	972	0	973	0	1	0
Shale, black, few gray layers, 1,023 ft still shows effects of heat	973	0	1,028	6	55	6
Shale, black, few light-colored lumps, bad cave 1,041 ft	1,028	6	1,041	0	12	6
Shale, black, normal to touch and eye, inclined to cave, 1,052 ft to 1,062 ft 2 in. lost	1,041	0	1,062	2	21	2
Shale, black broken	1,062	2	1,064	8	2	6
Shale, black, pyrite, 1,070 ft, broken and slickensided 1,073 ft to 1,074 ft. Calcareous and hard 1,075 ft and 1,080 ft, burnt a little 1,080 ft 6 in. to 1,084 ft 5 in [2]	1,064	8	1,084	5	19	9
Diabase sill, both top and bottom contacts clear cut 15° to 20° dip	1,084	5	1,099	11	15	6
Shale, black, little pyrite, burnt to 1,107 ft	1,099	11	1,107	0	7	1
Shale, black, slickensided and broken, some core lost	1,107	0	1,132	7	25	7
Shale, sandy or silty, gray	1,132	7	1,133	5	0	10
Shale, black, much broken, core lost	1,133	5	1,134	2	0	9
Shale, gray	1,134	2	1,135	11	1	9
Shale, black	1,135	11	1,136	9	0	10
Sandstone, gray, fine-grained	1,136	9	1,137	0	0	3
Shale, dark-gray, black, broken places	1,137	0	1,140	6	3	6
Sandstone, gray	1,140	6	1,140	10	0	4
Shale, gray to black, much broken, core lost	1,140	10	1,154	0	13	2
Shale, gray	1,154	0	1,155	0	1	0
Sandstone, gray, fine-grained	1,155	0	1,157	0	2	0
Shale, black, broken	1,157	0	1,158	0	1	0
Shale, gray, broken	1,158	0	1,160	0	2	0
Sandstone, gray	1,160	0	1,162	0	2	0
Shale, gray	1,162	0	1,163	0	1	0
Coal or coaly shale, several lumps calcareous sandstone in coal	1,163	0	1,163	2	0	2
Shale, gray, broken; like underclay	1,163	2	1,169	10	6	8
Sandstone, light-gray, fine-grained	1,169	10	1,171	0	1	2
Shale, gray, much slickensided and broken	1,171	0	1,174	7	3	7
Shale, gray, hard, like underclay	1,174	7	1,180	0	5	5
Sandstone, gray, fine-grained, somewhat shaly	1,180	0	1,188	10	8	10
Shale, gray, slightly sandy	1,188	10	1,191	1	2	3
Pekin formation (Triassic):						
Shale, gray, and gray sandstone, crossbedded, pinkish cast 1,195 ft, definitely pinkish 1,207 to 1,210 ft	1,191	1	1,210	0	18	11

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 7—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Pekin formation (Triassic)—Con.						
Sandstone, pinkish, gray, fine-grained, ¼ in. carbon flecks 1,213 ft 8 in., ⅛ in. carbon flecks 1,215 ft. More or less slickensided	1,210	0	1,217	0	7	0
Sandstone, gray	1,217	0	1,223	0	6	0
Shale, red	1,223	0	1,224	0	1	0
Sandstone, gray, fine- to medium-grained	1,224	0	1,228	0	4	0
Shale, red and gray variegated, very slightly sandy	1,228	0	1,247	0	19	0
Bottom of hole	1,247	0	------	------	------	------

[1] In this record the term "shale, red" probably refers in part to reddish-brown claystone

[2] Probably a fault zone, possibly the Gulf fault or a branch of this fault. The Cumnock and Gulf coal beds are probably cut out by this fault.

Drill hole BDH 8.
Location: Approximately 26,800 feet S. 57° W. of main shaft of Cumnock mine, Lee County.
Surface altitude: 280 (approximate).
Date: 1945.
Drilled for: Walter Bledsoe & Co.
Logged by: W. E. Berry, Duke University.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Terrace gravel deposits (Quaternary):						
No core	0	------	66	------	66	0
Sanford formation (Triassic):						
Basalt, weathered open joints more or less horizontal to 125 ft, even-textured to 166 ft then finer, few vertical joints, some calcite-healed fissures at all angles	66	------	206	6	140	6
Shale, purple, hard, burnt, some mottling with gray lumps	206	6	244	0	37	6
Siltstone, gray, crossbedded sandy	244	0	256	8	12	8
Shale, dark-gray	256	8	264	6	7	10
Shale, gray (looks like cement)	264	6	267	11	3	5
Shale, gray	267	11	268	3	0	4
Sandstone, light-gray, crossbedded	268	3	272	0	3	9
Shale, dark-gray, hard, broken	272	0	278	6	6	6
Sandstone, light-gray	278	6	281	6	3	0
Shale, gray, sandy	281	6	284	8	3	2
Shale, gray	284	8	286	0	1	4
Sandstone, gray, fine-grained	286	0	287	6	1	6
Shale, dark-gray	287	6	289	8	2	2
Sandstone, light-gray, fine-grained	289	8	290	8	1	0
Shale, gray, hard	290	8	300	0	9	4
Sandstone, light-gray, 307 ft 4 in. to 307 ft 6 in. Lumps black carbonaceous sandstone	300	0	307	6	7	6
Shale, dark-gray	307	6	314	0	6	6
Sandstone, gray and purple, crossbedded	314	0	316	0	2	0
Shale, deep-purple, gray, silty	316	0	319	4	3	4
Shale, gray, sandy	319	4	321	0	1	8
Shale, dark-purple, gray	321	0	325	0	4	0
Sandstone, gray, fine-grained	325	0	328	0	3	0
Shale, dark-purple, gray	328	0	330	6	2	6
Siltstone, dark-purple, gray	330	6	333	0	2	6
Sandstone, light-gray, cement-like	333	0	335	6	2	6
Shale, dark-purple, gray	335	6	338	0	2	6
Sandstone, light-gray, fine-grained	338	0	339	6	1	6
Shale, purple	339	6	343	3	3	9
Sandstone, light-gray, fine-grained, cement-like	343	3	348	0	4	9
Shale, gray, sandy	348	0	352	0	4	0
Shale, gray, slickensided 356 ft	352	0	358	0	6	0
Shale, reddish-gray, some brick-red lumps, all more or less sandy	358	0	365	6	7	6
Sandstone, gray, crossbedded	365	6	378	6	13	0
Sandstone, red	378	6	383	0	4	6
Sandstone, red and gray, crossbedded	383	0	425	0	42	0
Siltstone, red, shaly, worm tracks	425	0	429	6	4	6
Sandstone, gray, crossbedded	429	6	430	4	0	10

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 8—Continued

Description[1]	Depth from surface: From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
Sanford formation (Triassic)—Con.						
Siltstone, mottled red and gray	430	4	433	0	2	8
Siltstone, gray	433	0	436	0	3	0
Shale, dark-gray, crushed	436	0	436	6	0	6
Siltstone and sandstone, purple	436	6	452	6	16	0
Siltstone, gray	452	6	457	0	4	6
Shale, gray	457	0	460	4	3	4
Basalt, dark, low olivine, contact even, fine-grained for 6 in. Injected fine basalt 531 ft to 531 ft 6 in., 538 ft 5 in. to 539 ft 8 in., 550 ft to 550 ft 9 in., 560 ft to 567 ft 7 in.; one side of core fine, other coarse 624 ft to 650 ft. Brecciated 650 ft 7 in. to 652 ft and black (Fault), very fine-grained material with one black *Coprolite*-like lump with pyrite center 652 ft 8 in. to 753 ft 6 in.; slightly brecciated 680 ft to 681 ft. Fine, even contact with shale below	460	4	681	11	221	7
Cumnock formation (Triassic):						
Shale, black, crushed, shows little effect of heat	681	11	685	4	3	5
Sandstone, gray, medium-grained	685	4	686	0	0	8
Shale, black, soft, crushed	686	0	688	6	2	6
Sandstone, gray, fine- to medium-grained	688	6	689	6	1	0
Shale, black, crushed	689	6	692	9	3	3
Shale, gray to dark-gray	692	9	696	0	3	3
Shale, gray to sandy	696	0	701	0	5	0
Shale and sandstone layers. Shale, gray; sandstone, light-gray, fine- to medium-grained	701	0	709	6	8	6
Sandstone, black, carbonaceous, fine- to medium- grained	709	6	710	4	0	10
Shale and sandstone layers. Shale, gray; sandstone, light-gray, fine- to medium-grained	710	4	713	0	2	8
Sandstone, black, carbonaceous, fine- to medium-grained	713	0	714	11	1	11
Shale and sandstone layers. Shale, gray; sandstone, light-gray, fine- to medium-grained	714	11	717	0	2	1
Shale, black, soft, slickensided, sandy 720 ft to 721 ft, 728 ft to 729 ft, 734 ft *Estheria, Coprolites*	717	0	734	8	17	8
Shale, dark-gray	734	8	757	0	22	4
Shale, dark-gray to black, *Ostracods* 759 ft	757	0	767	0	10	0
Shale, gray, and sandstone, light-gray, fine-grained, *Coprolites*	767	0	769	1	2	1
Shale, light-gray, slightly sandy	769	1	779	11	10	10
Shale and sandstone, gray, fine-grained	779	11	780	11	1	0
Shale, gray, crushed	780	11	784	0	3	1
Shale, dark-gray to black, *Coprolites*	784	0	788	0	4	0
Shale, gray, sandy	788	0	793	0	5	0
Shale, black, *Coprolites*	793	0	805	0	12	0
Shale, gray	805	0	807	0	2	0
Shale, black	807	0	812	10	5	10
Siltstone (?), gray	812	10	818	0	5	2
Shale, gray	818	0	821	3	3	3
Shale, black	821	3	827	0	5	9
Shale, gray, slightly sandy	827	0	850	0	23	0
Shale, gray, sandy, scattered lenses of light-gray, fine-grained, crossbedded sandstone	850	0	861	0	11	0
Shale and sandstone, dark-gray	861	0	862	0	1	0
Shale, gray, sandy, pyrite, cross-bedded, burnt	862	0	875	8	13	8
Shale, dark-gray, sandy, burnt, pyrite	875	8	878	2	2	6
Shale, gray, sandy, much pyrite, burnt	878	2	882	0	3	10
Shale, black, burnt	882	0	887	0	5	0
Shale, gray, burnt	887	0	894	0	7	0
Shale, black, burnt	894	0	905	0	11	0
Shale, dark-gray, sandy, burnt	905	0	906	0	1	0
Sandstone, dark-gray, with light spots 1/16 in. diameter, burnt	906	0	913	8	7	8
Shale, dark-gray, burnt	913	8	915	8	2	0
Shale, black, burnt	915	8	919	4	3	8
Shale, gray, sandy, burnt	919	4	921	0	1	8
Shale, light-gray, mottled with faint pinkish tinge, burnt	921	0	932	0	11	0

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 8—Continued

Description[1]	Depth from surface: From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
Cumnock formation (Triassic)—Con.						
Shale, light-gray, pinkish-red partings, *Coprolites*, burnt. This pinkish cast may be due to the basalt below as *Coprolites* are common in Cumnock formation only	932	0	933	11	1	11
Basalt, fine-grained	933	11	937	0	3	1
Basalt, coarse-grained	937	0	1,027	9	90	9
Shale, dark-gray, banded, burnt, hard	1,027	9	1,030	9	3	0
Shale, gray, slightly pinkish, burnt	1,030	9	1,034	1	3	4
Shale, light-gray, burnt	1,034	1	1,044	0	9	11
Shale, dark-gray, burnt	1,044	0	1,047	2	3	2
Shale, dark-gray, slightly burnt	1,047	2	1,049	10	2	8
Shale, dark-gray	1,049	10	1,053	0	3	2
Shale, black, few gray layers	1,053	0	1,068	0	15	0
Shale, dark-gray and black, *Estheria* and *Ostracods* in black which is thin-bedded	1,068	0	1,126	0	58	0
Shale, dark-gray and black; *Estheria, Ostracods*, and *Coprolites* in black	1,126	0	1,145	0	19	0
Shale, black, few gray layers, *Coprolites* 1,163 ft	1,145	0	1,163	1	18	1
Sandstone, gray, fine-grained, calcareous	1,163	1	1,163	6	0	5
Shale, dark-gray and gray, few sand layers	1,163	6	1,165	4	1	10
Sandstone, gray, calcareous	1,165	4	1,166	0	0	8
Shale, dark-gray	1,166	0	1,166	6	0	6
Sandstone, gray, calcareous	1,166	6	1,167	6	1	0
Shale, dark-gray and black, *Coprolites*, sandy layer 1,170 ft 6 in	1,167	6	1,171	0	3	6
Shale, black, few dark-gray layers. Sandy layers 1,174 ft 6 in. to 1,175 ft, many *Coprolites*	1,171	0	1,184	6	13	6
Shale, black, few dark gray layers, some very carbonaceous, few sandy layers	1,184	6	1,204	1	19	7
Shale, black, *Estheria, Ostracods, Coprolites*	1,204	1	1,210	7	6	6
Sandstone, fine-grained, gray and dark-gray shale	1,210	7	1,211	2	0	7
Shale, black	1,211	2	1,211	9	0	7
Sandstone, light-gray and gray; even-bedded except last 5 inches	1,211	9	1,213	6	1	9
Shale, black, thin-bedded	1,213	6	1,214	2	0	8
Shale, black, broken and slickensided, somewhat coaly looking	1,214	2	1,214	4	0	2
Shale, black	1,214	4	1,221	0	6	8
Shale, dark-gray, sandy	1,221	0	1,222	4	1	4
Shale, dark-gray	1,222	4	1,223	0	0	8
Sandstone, gray, fine-grained	1,223	0	1,223	11	0	11
Shale, gray	1,223	11	1,224	6	0	7
Shale, black	1,224	6	1,224	8	0	2
Shale, gray and dark-gray, sandy layers, *Coprolites*	1,224	8	1,240	7	15	11
Shale, black, *Coprolites, Ostracods*	1,240	7	1,243	3	2	8
Shale, black, brownish tinge on scraping; occasional layer of gray, shale, *Ostracods* and *Coprolites*	1,243	3	1,255	6	12	3
Shale, black	1,255	6	1,270	5	14	11
Coal (Top bench, Cumnock Coal Bed)	1,270	5	1,272	11	2	6
Shale, black	1,272	11	1,273	3½	0	4½
Coal (Main bench, Cumnock Coal Bed), lower part somewhat coked, last 2¼ in. crushed and broken	1,273	3½	1,276	4½	3	1
Blackband	1,276	4½	1,277	9½	1	5
Coaly material—badly crushed (Lower bench, Cumnock Coal Bed)	1,277	9½	1,278	3½	0	6
Shale, black, carbonaceous	1,278	3½	1,279	2½	0	11
Shale, brownish-black	1,279	2½	1,279	10	0	7½
Coal (Lower bench, Cumnock Coal Bed), cokey	1,279	10	1,280	10	1	0
Shale, black	1,280	10	1,283	0	2	2
Shale, gray, sandy, pyrite 1,295 ft 6 in	1,283	0	1,295	6	12	6
Diabase	1,295	6	1,299	0	3	6
Shale, black, burnt	1,299	0	1,300	0	1	0
Sandstone, light- and dark-gray, fine-grained	1,300	0	1,303	5	3	5
Shale and sandstone, black	1,303	5	1,304	6	1	1
Sandstone, light-gray	1,304	6	1,305	7	1	1
Shale, gray to light-gray like fire clay	1,305	7	1,309	8	4	1

See footnote at end of table

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 8—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Coal (Gulf Coal Bed)	1,309	8	1,310	9½	1	1½
Sandstone, black and gray, fine-grained	1,310	9½	1,311	2½	0	5
Sandstone, light-gray, fine-grained	1,311	2½	1,313	0	1	9½
Bottom of hole	1,313	0				

[1] In this record the term "shale, red" probably refers in part to reddish-brown claystone.

Drill hole BDH 9.
Location: Approximately 19,300 feet S. 65° W. of main shaft of Cumnock mine, Lee County.
Surface altitude: 250 (approximate).
Date: 1945.
Drilled for: Walter Bledsoe & Co.
Logged by: W. E. Berry, Duke University.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Surface soil:						
No core	0		30		30	
Sanford formation (Triassic):						
Basalt sill, much weathered 50 to 58 ft; broken 106 ft 2 in.; lower contact indefinite	30		135		105	
Shale, dark-gray, burnt	135		142		7	
Sandstone, light-gray, fine- to medium-grained	142		145	2	3	2
Siltstone, dark-red, purple, arkosic	145	2	151		5	10
Shale, purple, red, sandy	151		195		44	
Sandstone, light-gray, medium- to very coarse-grained, arkosic pebbles up to ½ in. in diameter	195		213	6	18	6
Shale, light-gray to gray, purple cast	213	6	217		3	6
Sandstone, light-gray, few coarse layers	217		241		24	
Shale, gray, soft	241		242		1	
Shale, red	242		260	10	18	10
Siltstone, red, very micaceous	260	10	263		2	2
Shale, red, brick-red lumps	263		264	6	1	6
Shale, red, sandy	264	6	269		4	6
Sandstone, light- to medium-gray, micaceous, finer at base	269		298		29	
Shale, red, soft	298		331		33	
Siltstone, red, and layers of mottled red shale	331		371	9	40	9
Shale, red mottled	371	9	391	6	19	6
Shale, red, sandy in spots	391	6	429	6	38	
Sandstone, gray, fine-grained	429	6	433		3	6
Siltstone, red and light-pink	433		437	6	4	6
Shale, red	437	6	439	4	1	10
Siltstone, red, few gray layers	439	4	453	6	14	2
Sandstone, gray, fine-grained	453	6	455		1	6
Shale, variegated, red and gray	455		462	9	7	9
Sandstone, gray, arkosic	462	9	463	8	0	11
Shale, red	463	8	465		1	4
Sandstone, gray, fine- to coarse-grained, arkosic; oil saturated (tar-like) in coarse part	465		476	8	11	8
Sandstone, gray, fine-grained	476	8	477	6	0	10
Siltstone, red	477	6	484		6	6
Sandstone, pinkish-gray and shaly	484		489		5	
Shale, red mottled	489		502		13	
Sandstone, gray, variegated, fine-grained	502		505	8	3	8
Shale, red, silty	505	8	520		14	4
Siltstone, red	520		556		36	
Shale, red	556		565	5	9	5
Sandstone, gray, fine- to medium-grained	565	5	581	6	16	1
Sandstone, gray, medium-grained, arkosic, oily odor. Saturated and oozing light oil 583 ft to 583 ft 4 in., 584 ft 3 in. to 584 ft 5½ in.; 585 ft 5 in. to 586 ft 3 in.	581	6	586	3	4	9
Sandstone, gray, fine-grained	586	3	591		4	9
Shale, red	591		604	3	13	3
Sandstone, gray, fine-grained	604	3	606	4	2	1

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 9—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Shale, red, soft	606	4	613		6	8
Siltstone, red	613		615	10	2	10
Sandstone, gray, occasional shale layers	615	10	624		8	2
Shale, red	624		629		5	
Siltstone, red, and gray sandstone, fine-grained; alternate layers 1 ft 3 in. thick	629		645		16	
Shale, red	645		657		12	
Sandstone, gray, fine-grained, occasional red lump	657		678		21	
Shale, red, occasional fine-grained gray sandstone layer	678		700		22	
Sandstone, gray, fine-grained, and red siltstone	700		723		23	
Shale, red, soft	723		740		17	
Cumnock formation (Triassic):						
Shale, gray, sandy	740		770		30	
Shale, gray, soft	770		777	2	7	2
Sandstone, gray, crossbedded, fine-grained	777	2	785	4	8	2
Shale, black, calcite partings, and *Coprolites*	785	4	799		13	8
Sandstone, gray, fine-grained	799		801		2	
Sandstone, shaly and crushed	801		810		9	
Shale, gray to black	810		811		1	
Shale, black, sandy, carbonaceous streak at 822 ft	811		827		16	
Shale, black	827		827	8	0	8
Shale and sandstone, black	827	8	839		11	4
Shale, black, thin-bedded	839		855		16	
Siltstone, gray	855		860		5	
Sandstone, gray, medium-grained	860		871		11	
Sandstone, gray, fine-grained	871		873		2	
Shale, gray, hard, burnt	873		878		5	
Shale, light-gray, burnt	878		879	10	1	10
Basalt	879	10	984	8	104	10
Shale, gray, burnt, hard. Much gas 992 ft to 992 ft 6 in. Blew out water	984	8	1,014	3	29	7
Basalt sill, contact 25°	1,014	3	1,021	8	7	5
Shale, gray, burnt, occasional pinkish spot. Calcite crystals at contact with sill	1,021	8	1,038		16	4
Basalt	1,038		1,038	4		4
Shale, gray, burnt	1,038	4	1,059	10	21	6
Basalt	1,059	10	1,068		8	2
Shale, gray, burnt, oily at 1,076 ft 6 in., chunk black, burnt shale at 1,079 ft 4 in.	1,068		1,079	6	11	6
Sandstone, gray, burnt	1,079	6	1,079	9	0	3
Sandstone, gray, burnt, oily at 1,080 ft 9 in. and 1,083 ft 6 in., calcite lined and oil soaked	1,079	9	1,103		23	3
Shale, gray, light, hard, burnt	1,103		1,139	6	36	6
Shale, gray, light, hard	1,139	6	1,155		15	6
Shale, gray, hard, burnt (?)	1,155		1,183		28	
Shale, light-gray	1,183		1,196	10	13	10
Shale, gray	1,196	10	1,197	10	1	
Sandstone, gray, crossbedded, few carbon flakes	1,197	10	1,199	6	1	8
Shale, gray, hard	1,199	6	1,210	4	10	10
Basalt	1,210	4	1,211	7	1	3
"Breccia"	1,211	7	1,212			5
Basalt	1,212		1,218	11	6	11
Shale, black, burnt	1,218	11	1,223	2	4	3
Basalt sill, good clean contact	1,223	2	1,226	3	3	1
Shale, black, burnt, much pyrite	1,226	3	1,293	9	67	6
Basalt, badly broken and sandy, caves badly. (Had to cement.)	1,293	9	1,297	9	4	
Shale, black, less burnt below 1,311 ft	1,297	9	1,316		18	3
Shale, black, and dark-gray, some pyrite, few hard spots	1,316		1,349	2	33	2
Shale, black, thin-bedded, occasional slickensides, 1,352 ft 6 in. a layer looking sort of like coal but too heavy	1,349	2	1,378	8	29	6
Shale, gray, limy	1,378	8	1,379			4
Sandstone, gray, fine-grained, grading into siltstone and gray shale	1,379		1,380		1	
Shale, black, thin-bedded	1,380		1,382	1	2	1
Shale, gray	1,382	1	1,383			11
Shale and sandstone, gray, fine-grained	1,383		1,384	3	1	3
Shale, black, soft	1,384	3	1,386		1	9
Sandstone, gray, fine-grained, calcareous	1,386		1,386	6	0	6
Shale, black, thin-bedded	1 386	6	1,399		12	6

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 9—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Shale, black, thin-bedded, caved badly	1,399	------	1,403	4	4	4
Shale, black, hard, *Coprolites*	1,403	4	1,407	4	4	------
Shale, black, hard, slickensided at 1,408 ft to 1,409 ft, distorted and slightly brecciated	1,407	4	1,409	4	2	------
Shale, black, highly distorted, *Coprolites*, all dipping steeply	1,409	4	1,411	5	2	1
Coal (Top bench, Cumnock Coal Bed)	1,411	5	1,413	1	1	8
Shale, black	1,413	1	1,414	5	1	4
Coal (Main bench, Cumnock Coal Bed)	1,414	5	1,418	2	3	9
Shale, black	1,418	2	1,420	------	1	10
Coal (Lower bench, Cumnock Coal Bed), high ash from looks	1,420	------	1,421	5	1	5
Coal (Lower bench, Cumnock Coal Bed)	1,421	5	1,423	2½	1	9½
Shale, black	1,423	2½	1,424	8	1	5½
Sandstone, gray, fine-grained	1,424	8	1,425	2	0	6
Bottom of hole	1,425	2	------	------	------	------

[1] In this record the term "shale, red" probably refers in part to reddish-brown claystone.

Drill hole BDH 10.
Location: Approximately 2,700 feet N. 83° W. of main shaft of Cumnock mine, Chatham County.
Surface altitude: 217.
Date: 1945.
Drilled for: Walter Bledsoe & Co.
Logged by: W. E. Berry, Duke University.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Alluvium (Quaternary):						
No core	0	------	33	------	33	------
Cumnock formation (Triassic):						
Shale, gray, soft, gradually darkening, *Coprolites*	33	------	47	------	14	------
Shale, black, *Coprolites*	47	------	54	2	7	2
Shale, black, harsh to touch; scattered "burnt" coaly-looking layers, but too heavy for coal	54	2	61	11	7	9
Basalt, serpentine layers, some almost white clay layers	61	11	70	2	8	3
Shale, black, burnt, bad caving and loss of core	70	2	71	10	1	8
Lost	71	10	72	7½	0	9½
Coke (Main bench, Cumnock Coal Bed)	72	7½	74	6	1	10½
Lost (Reamed and cased and cleared)	74	6	74	11	0	5
Coke (Main bench, Cumnock Coal Bed), ground and chipped bnt in core barrel, apparently giving 4 ft ½ in. coke	74	11	76	8	1	9
Blackband	76	8	78	4	1	8
Shale, black, very soft and sticky	78	4	81	9	3	5
Shale, black, soft sticky	81	9	84	9	3	------
Shale and sandstone. Shale, gray, very fine-grained and slippery; sandstone, white, fine-grained, layers 1/16 in. to ½ in.	84	9	91	6	6	9
Shale, dark-gray, with few lumps of coal 96 ft to 96 ft 6 in	91	6	97	------	5	6
Shale, gray, very soft and talc-like	97	------	99	6	2	6
Sandstone, gray, fine-grained, shaly	99	6	101	5	1	11
Shale, gray, soft	101	5	101	9	0	4
Sandstone, gray, fine- to very fine-grained, shaly	101	9	114	------	12	3
Shale, gray, slippery	114	------	115	------	1	------
Shale, dark-gray to black, not slippery, hard	115	------	117	2	2	2
Coal (Gulf Coal Bed)	117	2	117	7½	0	5½
Bone	117	7½	117	11½	0	4
Coal (Gulf Coal Bed)	117	11½	118	0	0	½
Bone	118	------	118	4½	0	4½
Coal (Gulf Coal Bed)	118	4½	118	11	0	6½
Shale, black, coaly	118	11	119	3	0	4

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 10—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Shale, gray, black	119	3	122	1½	2	10½
Coal (Gulf Coal Bed)	122	1½	122	4	0	2½
Shale, gray, lumps of coal up to ½ in	122	4	124	------	1	8
Shale, gray, soft	124	------	126	------	2	------
Bottom of hole	126	------	------	------	------	------

[1] In this record the term "shale, red" probably refers in part to reddish-brown claystone.

Drill hole BDH 11.
Location: Approximately 2,700 feet N. 85° W. of main shaft of Cumnock mine, Chatham County.
Surface altitude: 217.
Date: 1945.
Drilled for: Walter Bledsoe & Co.
Logged by: W. E. Berry, Duke University.

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Alluvium (Quaternary):						
No core	0	------	33	------	33	------
Cumnock formation (Triassic):						
Shale, gray, soft	33	------	62	1	29	1
Shale, gray, hard cutting	62	1	64	9	2	8
Shale, gray, hard, fast slacking, hard calcite layer 83 ft. 3 in	64	9	83	------	18	3
Shale, gray, hard, caving	83	------	88	------	5	------
Shale, gray, hard, calcareous	88	------	88	7	0	7
Shale, dark-gray to black, *Coprolites*, caving below 92 ft	88	7	93	9	5	2
Shale, hard, and very calcareous	93	9	94	------	0	3
Shale, black, *Coprolites*, difficult to core, some very soft mud-like layers lost	94	------	112	------	18	------
Shale, black, few *Coprolites*	112	------	118	------	6	------
Shale, dark-gray, calcite partings broken, tar at 119 ft	118	------	123	6	5	6
Shale, black to dark-gray, calcite stringers, few *Coprolites*	123	6	157	------	33	6
Shale, gray, tar in partings	157	------	166	5	9	5
Shale, light-gray	166	5	172	------	5	7
Shale, black, waxy, *Coprolites*	172	------	186	8	14	8
Shale, brown	186	8	186	9	------	1
Shale, light-gray, talc-like, soft, slippery	186	9	187	2	0	5
Shale, brown	187	2	187	3	------	1
Shale, black	187	3	187	4	------	1
Shale, gray, soft	187	4	189	------	1	8
Shale, black	189	------	191	7	2	7
Shale, light-gray, talc-like, soft, slippery	191	7	192	3	------	8
Shale, black	192	3	195	6	3	3
Basalt	195	6	202	9	7	3
Shale, black, burnt	202	9	206	------	3	3
Shale, gray, burnt, some burnt-out coal fragments	206	------	207	6	1	6
Shale, gray, soft	207	6	207	10	------	4
Coal (Main bench, Cumnock Coal Bed)	207	10	210	10	3	------
Shale, blackband	210	10	212	4	1	6
Coal (Lower bench, Cumnock Coal Bed)	212	4	213	10	1	6
Shale, black	213	10	214	3	------	5
Coal (Lower bench, Cumnock Coal Bed)	214	3	215	------	------	9
Shale, black	215	------	216	------	1	------
Coal (Lower bench, Cumnock Coal Bed)	216	------	216	2½	------	2½
Shale, black, slightly sandy	216	2½	218	6	2	3½
Shale and sandstone, alternate layers of gray shale and light-gray fine-grained sandstone	218	6	229	9	11	3
Shale, gray to dark-gray, soft	229	9	232	6	2	9
Sandstone, light-gray, few shale partings	232	6	234	8	2	2
Shale, gray, soft	234	8	235	6	------	10
Sandstone, light-gray, shale partings	235	6	248	------	12	6
Shale, dark-gray to black, *Coprolites*	248	------	252	2	4	2

See footnote at end of table.

DIAMOND-DRILL RECORDS—Continued

Drill hole BDH 11—Continued

Description [1]	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Cumnock formation (Triassic)—Con.						
Coal (Gulf Coal Bed)	252	2	253	11½	1	9½
Shale, black, calcareous	253	11½	254	3		3½
Shale, black, few calcite stringers and coal fragments	254	3	257		2	9
Bottom of hole	257					

[1] In this record the term "shale, red" probably refers in part to reddish-brown claystone.

Drill hole BMDH DR-1.
Location: Approximately 10,200 feet S. 35° W. of main shaft of Cumnock mine, Chatham County.
Surface altitude: 246.
Date: 1947–48.
Drilled for: U. S. Bureau of Mines.
Logged by: John A. Reinemund, U. S. Geological Survey.

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
River terrace deposits (Quarternary):						
Clay, sand, and gravel. No core	0		26		26	
Sanford formation (Triassic):						
Claystone, moderate reddish-brown (10R4/6), hard, with worm-like markings. Scattered round patches of limestone and dendrites of manganese oxide	26		93		67	
Claystone, moderate reddish-brown (10R4/6), soft, with hard silty zones near bottom	93		225		132	
Sandstone, grayish-red (10R4/2), fine-grained at top to medium-grained at bottom, micaceous, crossbedded	225		232		7	
Sandstone, grayish-red (10R4/2), coarse-grained becoming conglomeratic toward base, contains gray and green subangular to subrounded fragments of quartzite and schist as much as 10 mm across. Interstitial patches of dark-red hematitic silt in lower part	232		234		2	
Claystone, moderate reddish-brown (10R4/6), soft, with worm-like markings and calcareous patches	234		250		16	
Siltstone, grayish-red (10R4/2), hard	250		254		4	
Claystone, moderate reddish-brown (10R4/6), soft	254		262		8	
Siltstone, grayish-red (10R4/2), hard	262		264		2	
Claystone, moderate reddish-brown (10R4/6), in alternating hard and soft layers with scattered calcareous patches	264		307		43	
Siltstone, dark reddish-brown (10R3/4), hard	307		308		1	
Claystone, moderate reddish-brown (10R4/6), hard. Worm-like impressions and plant remains	308		336		28	
Siltstone, dark reddish-brown (10R3/4), hard	336		338		2	
Claystone, moderate reddish-brown (10R4/6), hard. Bands and patches of limestone near the top	338		383		45	
Claystone, moderate reddish-brown (10R4/6), soft. Few scattered calcareous patches	383		408		25	
Siltstone, dark reddish-brown (10R3/4), hard, micaceous	408		423		15	
Claystone, moderate reddish-brown (10R4/6), soft, becoming silty and hard at bottom	423		442		19	
Sandstone, grayish red-purple (5RP4/2), micaceous with flakes up to 3 mm across; dip 11°	442		444		2	

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH DR-1—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Claystone, moderate reddish-brown (10R4/6), soft, slightly sheared. Scattered patches of green sandstone and yellowish-gray limestone; also blebs of hematite. Stylolites 470 ft–480 ft	444		484		40	
Siltstone, grayish-red (10R4/2), soft at top, micaceous and hard at bottom	484		489		5	
Sandstone, banded gray and red, medium-grained, micaceous with flakes as much as 2 mm across. Crossbedded	489		495		6	
Claystone, moderate reddish-brown (10R4/6), soft, fractured	495		507		12	
Claystone, light olive-gray (5Y6/1), highly calcareous, fractured. Bands of iron-rich red clay and hematite concentrated along fractures. Abundant bright slickensides. Fragments of original limy bed dip 25°	507		517		10	
Claystone, grayish-red (10R4/2), abundant slickensides, limy near top. Blebs of hematite as much as ½ in. across near bottom	517		530		13	
Claystone, moderate reddish-brown (10R4/6), soft	530		542		12	
Claystone, moderate reddish-brown (10R4/6), soft, mottled with irregular greenish-gray patches. Blebs and stringers of hematite 542 to 550 ft	542		560		18	
Siltstone, dark reddish-brown (10R3/4), structureless. Clayey and soft 560 to 575 ft	560		610		50	
Claystone, moderate reddish-brown (10R4/6), very soft. Pits and worm-like impressions	610		615		5	
Siltstone, dark reddish-brown (10R3/4), hard	615		620		5	
Claystone, moderate reddish-brown (10R4/6), very soft. Pits and worm-like impressions	620		628		8	
Siltstone, dark reddish-brown (10R3/4), with clayey zones	628		643		15	
Siltstone, moderate reddish-brown (10R4/6), micaceous, crossbedded, with clayey and sandy layers. Scattered calcareous patches and blebs of hematite. Stringers of blue clay in lower part	643		675		32	
Claystone, moderate reddish-brown (10R4/6), soft. Mottled with gray siltstone at bottom	675		680		5	
Sandstone, grayish-red (10R4/2), medium-grained, micaceous, with flakes as much as 2 mm across	680		685		5	
Sandstone, grayish-red (10R4/2), medium-grained at top grading downward into conglomerate consisting of gray, green, and pink quartz, quartzite, feldspar, and schist grains as much as 20 mm across in a dark reddish-brown (10R3/4), sandstone matrix	685		699		14	
Claystone, moderate reddish-brown (10R4/6), soft with hard silty patches near the top. Small, frosted quartz grains	699		754		55	
Siltstone, pale reddish-brown (10R5/4), micaceous in lower part	754		765		11	
Claystone, moderate reddish-brown (10R4/6), variable soft and hard	765		801		36	
Claystone, moderate reddish-brown (10R4/6), soft. Hard, silty zones 823 ft–833 ft and 888 ft–891 ft	801		904		103	
Siltstone, dark reddish-brown (10R3/4), very hard. Fine flakes of mica. Crossbedded	904		923		19	
Claystone, red to brown, soft, slightly sheared. Scattered irregular patches of brown and gray siltstone	923		986		63	

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH DR-1—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Claystone, moderate reddish-brown (10R4/6), soft	986		1,003		17	
Siltstone, moderate reddish-brown (10R4/6), hard	1,003		1,012		9	
Sandstone, light olive-gray (5Y6/1), coarse-grained grading to fine near bottom. Crossbedded, micaceous, arkosic	1,012		1,022		10	
Claystone, moderate reddish-brown (10R4/6), hard	1,022		1,028		6	
Siltstone, grayish-red (10R4/2), micaceous, hard, dip 10°	1,028		1,032		4	
Claystone, moderate reddish-brown (10R4/6), hard	1,032		1,037		5	
Siltstone, grayish-red (10R4/2), very hard. Light, micaceous layers with flakes as much as 2 mm across	1,037		1,042		5	
Sandstone, yellowish-gray (5Y7/2), coarse-grained, crossbedded, arkosic, and micaceous	1,042		1,052		10	
Claystone and siltstone in alternating beds averaging 5 ft thick. Hematite concentrations and oolitic texture 1,056 to 1,074 ft. Somewhat sheared and contorted below 1,090 ft. Siltstone is grayish-red (10R4/2), crossbedded, hard; claystone is moderate reddish-brown (10R4/6), soft	1,052		1,154		102	
Siltstone, moderate-brown (5YR-3/4), hard, micaceous; dip 10°. Fault at 1,161 ft dips 60°	1,154		1,161		7	
Claystone, moderate reddish-brown (10R4/6), hard	1,161		1,163		2	
Siltstone, dark reddish-brown (10R3/4), cut into slickensided slivers that have clay fracture coating	1,163		1,171		8	
Claystone, moderate reddish-brown (10R4/6), soft, contorted and fractured, with hard, gray seams along fractures. Wormlike markings	1,171		1,183		12	
Sandstone, yellowish-gray (5Y7/2), fine-grained, micaceous	1,183		1,184		1	
Claystone, moderate reddish-brown (10R4/6), soft, silty 1,185 to 1,189 ft. Gray claystone patches in lower part	1,184		1,191		7	
Sandstone, yellowish-gray (5Y7/2), fine-grained	1,191		1,192		1	
Claystone, moderate reddish-brown (10R4/6), soft	1,192		1,195		3	
Sandstone, yellowish-gray (5Y7/2), fine-grained	1,195		1,196		1	
Claystone, moderate reddish-brown (10R4/6), soft	1,196		1,197		1	
Sandstone, yellowish-gray (5Y7/2), fine-grained, massive	1,197		1,206		9	
Claystone and sandstone, dark reddish-brown (10R3/4), in irregular patches	1,206		1,213		7	
Sandstone, yellowish-gray (5Y7/2), crossbedded, with red claystone seams. Bottom 4 ft is conglomerate. Heavily micaceous. Brecciated	1,213		1,244		31	
Claystone, moderate reddish-brown (10R4/6), soft with irregular, thin, hard silty zones. Brecciated, with abundant slickensided fractures. Scattered blebs of hematite. Calcareous 1,285 to 1,287 ft	1,244		1,311		67	
Claystone, moderate reddish-brown (10R4/6), soft mottled with irregular patches of gray sandstone and gray calcareous claystone. Core in slickensided chips	1,311		1,334		23	
Claystone, moderate reddish-brown (10R4/6), soft, contorted, mottled with blebs of hematite and grayish-green calcareous patches. Slickensided fractures and stylolites	1,334		1,366		32	
Sandstone, dark reddish-brown (10R3/4), fine-grained, crossbedded, micaceous	1,366		1,372		6	
Claystone, moderate reddish-brown (10R4/6), soft, mottled with grayish-green non-calcareous and gray calcareous claystone. Micaceous and hard toward bottom. Slickensides 1,390 to 1,394 ft	1,372		1,394		22	
Siltstone, moderate-brown (5YR3/4), micaceous, shaly	1,394		1,398		4	
Claystone dark reddish-brown (10R3/4), crossbedded, calcareous zone 1,405 to 1,406 ft	1,398		1,408		10	
Sandstone, yellowish-gray (5Y7/2), fine-grained, crossbedded, micaceous	1,408		1,410		2	
Claystone, dark reddish-brown (10R3/4), mottled with bands and round patches of blue claystone, gray calcareous claystone and hematite	1,410		1,414		4	
Siltstone, dark reddish-brown (10R3/4), hard, micaceous	1,414		1,421		7	
Claystone, mottled red, purple, gray, and green, soft. Mostly sheared and contorted, with abundant slickensides. Sandy 1,450 to 1,480 ft. Calcareous 1,435 to 1,436 ft	1,421		1,502		81	
Claystone, mottled red, brown, gray, and green. Hard, crossbedded, micaceous; calcareous 1,504 to 1,506 ft. Slickensides 1,508 to 1,516 ft. Fish or invertebrate spine	1,502		1,520		18	
Sandstone, gray to red, medium-grained, micaceous, crossbedded. Dip 10°	1,520		1,524		4	
Claystone, mottled gray, red, and green, soft. Bands of gray limestone in upper part. Abundant flakes of mica as much as 2 mm across in lower part. Sheared 1,552 to 1,553 ft	1,524		1,553		29	
Claystone, light olive-gray (5Y6/1), calcareous, soft, with scattered blebs of hematite. Fractures lined with red clay	1,553		1,567		14	
Claystone, moderate reddish-brown (10R4/6), soft, scattered bluish-green patches	1,567		1,585		18	
Sandstone, light bluish-gray (5B7/1), crossbedded, heavily micaceous with flakes up to 3 mm across. Inter-bedded clay seams 1,585 to 1,590 ft	1,585		1,603		18	
Claystone, mottled gray and red, hard to soft. Badly sheared, with abundant slickensides. Gray claystone and hematite concentrated by selective solution along fractures	1,603		1,681		78	
Claystone, moderate reddish-brown (10R4/6), soft, mottled with hard, gray siltstone, especially toward bottom	1,681		1,726		45	
Siltstone, light olive-gray (5Y6/1), hard, massive. Contains scattered sheared patches of red claystone	1,726		1,744		18	
Claystone, moderate reddish-brown (10R4/6), soft, micaceous. Core in slickensided chips	1,744		1,757		13	
Claystone, dark reddish-brown (10R3/4), soft, mottled with patches of gray siltstone	1,757		1,762		5	
Siltstone, light olive-gray (5Y6/1), hard, micaceous, with irregular stringers of red clay. Calcareous patches	1,762		1,768		6	
Claystone, dark reddish-brown (10R3/4), soft, micaceons, sheared. Lowest red bed in Sanford formation	1,768		1,769		1	
Cumnock formation (Triassic):						
Claystone, medium-gray (N-5), soft, micaceous, noncalcareous	1,769		1,772		3	
Siltstone, medium dark-gray (N-4), micaceous, calcareous	1,772		1,776		4	
Claystone, medium-gray (N5), soft, sheared zones 1,776 to 1,779 ft and 1,788 to 1,791 ft mottled with brown patches	1,776		1,791		15	

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH DR-1—Continued

Description	Depth from surface From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
Cumnock formation (Triassic)—Con.						
Shale, grayish-black (N-2), sheared. Few calcite veinlets. Highest black shale in Cumnock formation	1,791		1,798		7	
Siltstone, banded and mottled with white limestone patches. Shaly toward bottom	1,798		1,806		8	
Shale, black (N1), coaly	1,806		1,807		1	
Siltstone, medium-gray (N5), with white calcareous layers. Interbedded coaly shale at 1,807 to 1,808 ft and 1,814 to 1,815 ft	1,807		1,824		17	
Shale, grayish-black (N2), sheared, carbonaceous. Abundant calcite veins	1,824		1,833		9	
Siltstone, medium dark-gray (N4), with coarse flakes of mica at top. Shaly at bottom	1,833		1,845		12	
Siltstone, sandstone and shale, interbedded. Siltstones and sandstones are gray, calcareous and micaceous. Shales are gray to black. Bituminous patches 1,849 to 1,850 ft. Dip [illegible]						

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH DR-1—Continued

Description	Depth from surface From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
Cumnock formation (Triassic)—Con.						
Shale, grayish-black (N2), fissile, non-calcareous but contains minute white calcite veinlets. Carbonaceous 1,955 ft to 1,960 ft. Internally sheared in upper part. Abundant fish scales, *Estheria* shells, and *Coprolites.* Dip 10°	1,955		1,964		9	
Shale, grayish-black (N2), massive, hard. Internally sheared. Pyrite grains at top. Slightly calcareous with scattered calcite vienlets	1,964		1,975		11	
Shale, black (N1), fissile, noncalcareous	1,975		1,980		5	
Shale, grayish-black (N2), hard, massive, calcareous. Calcite veinlets. Vugs at 1,985 ft coated with quartz crystals and filled with oil	1,980		1,987		7	
Shale, black (N1), soft, fissile, noncalcareous	1,987		1,989		2	
Shale, dark-gray (N3) to black (N1), hard, massive. Partly calcareous	[illegible]		[illegible]		[illegible]	

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH DR-1—Continued

Description	Depth from surface From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
Cumnock formation (Triassic)—Con.						
Shale, grayish-black (N2), fissile, noncalcareous, abundant plant fossils	2,296		2,298		2	
Siltstone, banded, medium-gray (N5) and dark-gray (N3), noncalcareous, with a few dark shaly bands containing plant fossils	2,298		2,303		5	
Sandstone, medinm-gray (N5), fine-grained, crossbedded, noncalcareous. Mottled with irregular bands and lenses of black, carbonaceous shale. *Coal* seams at 2,306 and 2,308 ft probably not over 1 in. thick	2,303		2,309		6	
Shale, grayish-black (N2) with abundant plant fossils, and sandstone, medium-gray (N5), fine-grained. Interbedded in ¼-in. alternating bands. Dip 6°	2,309		2,314		5	
Blackband	2,314		2,315		1	
Shale, banded gray and black; bands of black shale are carbonaceous	2,315		2,317	6	2	6
Claystone, medium-gray (N5), soft (fire clay)	2,317	6	2,318			6
Coal (Gulf Coal Bed), chemical analysis C-97932 (see table 10)	2,318		2,318	10½		10½
Blackband	2,318	10½	2,319	4½		6
Siltstone, medium-gray (N5), hard, mottled with thin bands and irregular stringers of soft, contorted, gray claystone containing plant fossils and scattered carbonaceous material. Crossbedded, noncalcareous	2,319	4½	2,328		8	7½
Bottom of hole	2,328					

Drill hole BMDH DR-2.
Location: Approximately 15,700 feet S. 49° W. of main shaft of Cumnock mine, Chatham County.
Surface altitude: 263.
Date: 1948.
Drilled for: U. S. Bureau of Mines.
Logged by: John A. Reinemund, U. S. Geological Survey.

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH DR-2—Continued

Description	Depth from surface From— Feet	From— Inches	To— Feet	To— Inches	Thickness Feet	Thickness Inches
Sanford formation (Triassic)—Con.						
Shale, grayish-black (N2), with thin calcite veinlets and scattered pyrite grains. Highest black shale in Cumnock formation	1,767		1,768		1	
Siltstone, medium light-gray (N6), very hard, mostly in fractured chips with calcite fracture coatings	1,768		1,771		3	
Shale, grayish-black (N2), fissile, with calcite coatings, pyrite grains and probable fossil impressions. Baked	1,771		1,772		1	
Diabase, fine-grained at top and bottom, medium-grained at center	1,772		1,777		5	
Siltstone, medium-gray (N5), very hard, micaceous and calcareous. Baked and blackened at top and bottom	1,777		1,785		8	
Diabase, medium-grained	1,785		1,789		4	
Diabase, coarse-grained. Considerably weathered along incipient cooling fractures with formation of relatively weak chloritic zones that give the rock a pitted "rotten" appearance. A few longitudinal fractures coated with chlorite and with slickensides parallel to the bedding	1,789		1,875		86	
Diabase, fine-grained	1,875		1,878		3	
Siltstone, medium dark-gray (N4), very hard	1,878		1,879		1	
Shale, banded gray and black, baked, very hard	1,879		1,880		1	
Claystone, medium dark-gray (N4), contorted, very hard, noncalcareous, with irregular dark-green patches	1,880		1,881		1	
Shale, banded gray and black, contorted, noncalcareous. Minute pyrite grains along bedding surfaces	1,881		1,882		1	
Claystone, dark-gray (N3), hard, with abundant round, white patches becoming larger and less numerous toward bottom. White patches in upper part of bed average 3 mm across and are slightly calcareous	1,882		1,887		5	
Siltstone, banded light and dark-						

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH DR-2—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Shale, banded light and dark-gray, calcareous, pyrite grains abundant; bedding flat	1,966		1,968		2	
Shale, grayish-black (N2), in part fissile and fossiliferous, calcareous	1,968		1,975		7	
Claystone, medium dark-gray (N4), silty, hard, internally sheared with a few calcite veinlets, calcareous; mottled, in part, with light-gray calcareous patches	1,975		1,992		17	
Shale, grayish-black (N2), fissile except for 6-in. claystone zone at center; noncalcareous	1,992		1,994		2	
Claystone, dark-gray (N3), silty, hard, calcareous; internally sheared	1,994		2,003		9	
Shale, grayish-black (N2), imperfectly bedded, internally sheared; slightly calcareous	2,003		2,007		4	
Claystone, medium dark-gray (N4), internally sheared, calcareous; white limy bands 2,015 to 2,018 ft	2,007		2,022		15	
Shale, grayish-black (N2), fissile, slightly calcareous, fossiliferous, *Estheria*	2,022		2,025		3	
Claystone, medium dark-gray (N4), with light-gray bands, silty, hard, very calcareous; internally sheared	2,025		2,034		9	
Shale, medium dark-gray (N4), fissile, slightly calcareous	2,034		2,035		1	
Claystone, medium dark-gray (N4), hard, calcareous, internally sheared	2,035		2,038		3	
Shale, grayish-black (N2), partly fissile and partly massive, slightly calcareous, somewhat sheared; few fossils	2,038		2,047		9	
Claystone, dark-gray (N3), silty, hard calcareous; internally sheared	2,047		2,061		14	
Shale, grayish-black (N2), banded with gray in upper 3 ft and bottom 1 ft fissile, slightly calcareous; internally sheared	2,061		2,071		10	
Claystone, mottled light greenish-gray (5GY6/1) siliceous patches and dark-gray (N3) non-siliceous patches. Highly contorted and internally sheared; calcareous, especially light patches	2,071		2,077		6	
Shale, grayish-black (N2), imperfect cleavage, internally sheared, very slightly calcareous	2,077		2,084		7	
Shale, grayish-black (N2), fissile, very slightly calcareous; contains a few fossils	2,084		2,089		5	
Claystone, dark-gray to black, internally sheared, calcareous	2,089		2,099		10	
Shale, grayish-black (N2), fissile, noncalcareous, fossiliferous	2,099		2,100		1	
Shale, grayish-black (N2), massive, internally sheared, noncalcareous	2,100		2,102		2	
Shale, grayish-black (N2), fissile, noncalcareous, fossiliferous	2,102		2,109		7	
Shale, grayish-black (N2), massive, partly calcareous, internally sheared	2,109		2,112		3	
Shale, grayish-black (N2), mostly fissile, internally sheared, partly calcareous. Contains a little carbonaceous material and a few fossils; core in slickensided chips	2,112		2,180		68	
Shale, grayish-black (N2), fissile, fossiliferous, mostly non-calcareous. Black silty zones 4 in. thick each at 2,180 ft, 2,181 ft, 2,183 ft, and 2,185 ft	2,180		2,185		5	
Shale, grayish-black (N2), fissile, non-calcareous	2,185		2,188		3	
Shale, grayish-black (N2), carbonaceous, fossiliferous, mostly non-calcareous	2,188		2,200		12	
Shale, black (N1), carbonaceous with abundant plant fossils	2,200		2,201		1	

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH DR-2—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Shale, grayish-black (N2), alternating 3-in. zones carbonaceous and non-carbonaceous, scattered fossils, internally sheared	2,201		2,203		2	
Shale, black (N1), carbonaceous, fossiliferous	2,203		2,205		2	
Shale, black (N1), very carbonaceous, non-calcareous; abundant plant fossils, fish scales and shells	2,205		2,225		20	
Shale, grayish-black (N2), fissile except 2,226 ft–2,227 ft which contains irregular silty stringers; scattered fossils, non-calcareous	2,225		2,228		3	
Shale, grayish-black (N2), fissile, non-calcareous, scattered fossils; 6-in black, silty zones at 2,229 ft and 2,230 ft and 3-in. silty zones at 2,232 ft, 2,233 ft, 2,233 ft, 6 in., 2,234 ft, 2,235 ft, and 2,238 ft	2,228		2,238		10	
Shale, black (N1), fissile, very carbonaceous grading into blackband in lower part, with blebs and stringers of coal; fossiliferous, non-calcareous	2,238		2,243	9	5	9
Bone or very carbonaceous shale in small, contorted chips with highly polished surfaces	2,243		2,244			3
Blackband, containing abundant blebs and streaks of coal	2,244		2,248		4	
Shale, grayish-black (N2), fissile, non-calcareous. Contains a few thin, carbonaceous zones and a few ½-in. silty zones; scattered coaly blebs and abundant plant fossils	2,248		2,260		12	
Siltstone, medium-gray (N5), non-calcareous, with interbedded dark-gray shaly seams containing plant fossils and coaly material; irregular white quartz stringers	2,260		2,264		4	
Shale, black (N1), fissile, non-calcareous, carbonaceous with coaly blebs and streaks	2,264		2,266		2	
Shale, black (N1), fissile, non-calcareous, few fossils	2,266		2,272		6	
Blackband, impregnated with coaly seams	2,272		2,274		2	
Shale, black (N1), fissile, non-calcareous, carbonaceous, abundant plant fossils	2,274		2,280		6	
Shale, dark-gray (N3), fissile, non-calcareous, with medium-gray, non-fissile, 3-in. silty zones at 2,281 ft, 2,282 ft, and a 6-in. silty zone at 2,284 ft; few fossils	2,280		2,285		5	
Siltstone, medium dark-gray (N4), hard, calcareous in lower part	2,285		2,287		2	
Shale, dark-gray (N3), with light-gray limy bands and stringers. Imperfect bedding; scattered fossils	2,287		2,291		4	
Shale, grayish-black (N2), massive or poorly bedded, non-calcareous. Abundant slickensides; few fossils	2,291		2,298		7	
Shale, black (N1), imperfectly bedded, carbonaceous, contains coaly blebs and seams; abundant plant fossils	2,298		2,302		4	
Shale, black (N1), fissile, non-calcareous; few fossils	2,302		2,304		2	
Shale, black (N1), fissile, carbonaceous, non-calcareous, impregnated with coaly seams; profusion of plant fossils	2,304		2,306		2	
Shale, grayish-black (N2), fissile, non-calcareous, few fossils, 2-in. silty zone at 2,306 ft; plant fossils in lower 3 ft	2,306		2,313		7	
Shale, black (N1), fissile, carbonaceous, calcareous, fossiliferous	2,313		2,314		1	
Claystone, dark-gray (N3), silty at top, calcareous	2,314		2,315		1	
Blackband, except for 3-in. silty zone at 2,321 ft. Sample 0–10 (see table 15). Sample N-15 (see table 16)	2,315		2,327	5	12	5
Coal (Top bench, Cumnock Coal Bed), shaly	2,327	5	2,328			7

DIAMOND-DRILL RECORDS—Continued

Drill hole BMDH DR-2—Continued

Description	Depth from surface				Thickness	
	From—		To—			
	Feet	Inches	Feet	Inches	Feet	Inches
Sanford formation (Triassic)—Con.						
Coal (Top bench, Cumnock Coal Bed), complete recovery. Chemical analysis D-5907 (see table 10)	2,328	------	2,329	------	1	------
Siltstone, medium-gray (N5), carbonaceous, with abundant dark-gray pont fossils. Sample O-11 (see table 15). Sample N-16 (see table 16)	2,329	------	2,330	5	1	5
Coal (Main bench, Cumnock Coal Bed), 29 in. of core recovered. The remainder is probably coal or shaly coal judging from the sludge and regional trends. Chemical analysis D-5908 (see table 10)	2,330	5	2,334	7	4	2
Blackband	2,334	7	2,334	10	------	3
Siltstone, medium-gray (N5), soft, with abundant plant fossils	2,334	10	2,337	10	3	------
Blackband. Sample O-12 (see table 15). Sample N-17 (see table 16)	2,337	10	2,339	4	1	6
Sanford formation (Triassic)—Con.						
Blackband, in small chips and washings. Sample O-12 (see table 15). Sample N-17 (see table 16)	2,339	4	2,340	------	------	8
Blackband with coal streaks. Sample O-12 (see table 15). Sample N-17 (see table 16)	2,340	------	2,340	10	------	10
Coal (Lower bench, Cumnock Coal Bed)	2,340	10	2,341	4	------	6
Blackband, impregnated with coaly seams; sheared. Sample O-13 (see table 15). Sample N-18 (see table 16)	2,341	4	2,343	1	1	9
Siltstone, dark-gray (N3) with white quartz bands and stringers. Crossbedded, non-calcareous; abundant plant fossils and a little carbonaceous material	2,343	1	2,350	------	6	11
Blackband	2,350	------	2,354	------	4	------
Bottom of hole	2,354	------	------	------	------	------

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